Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

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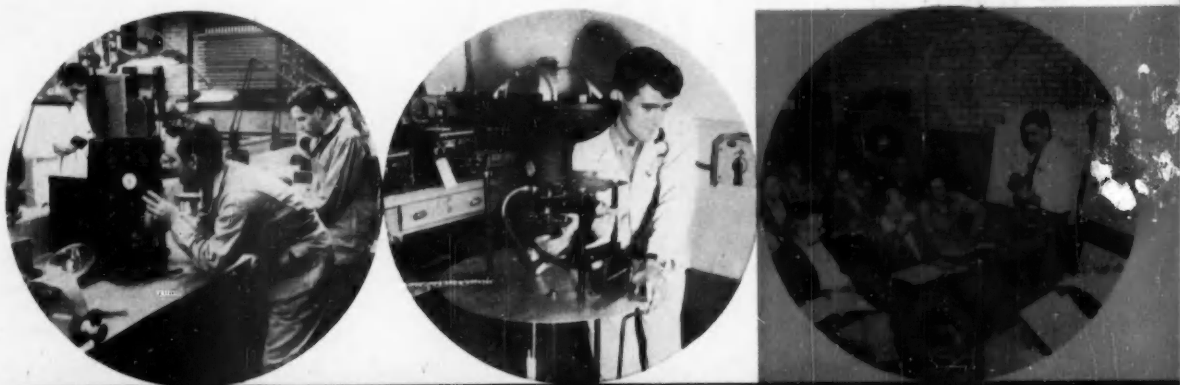
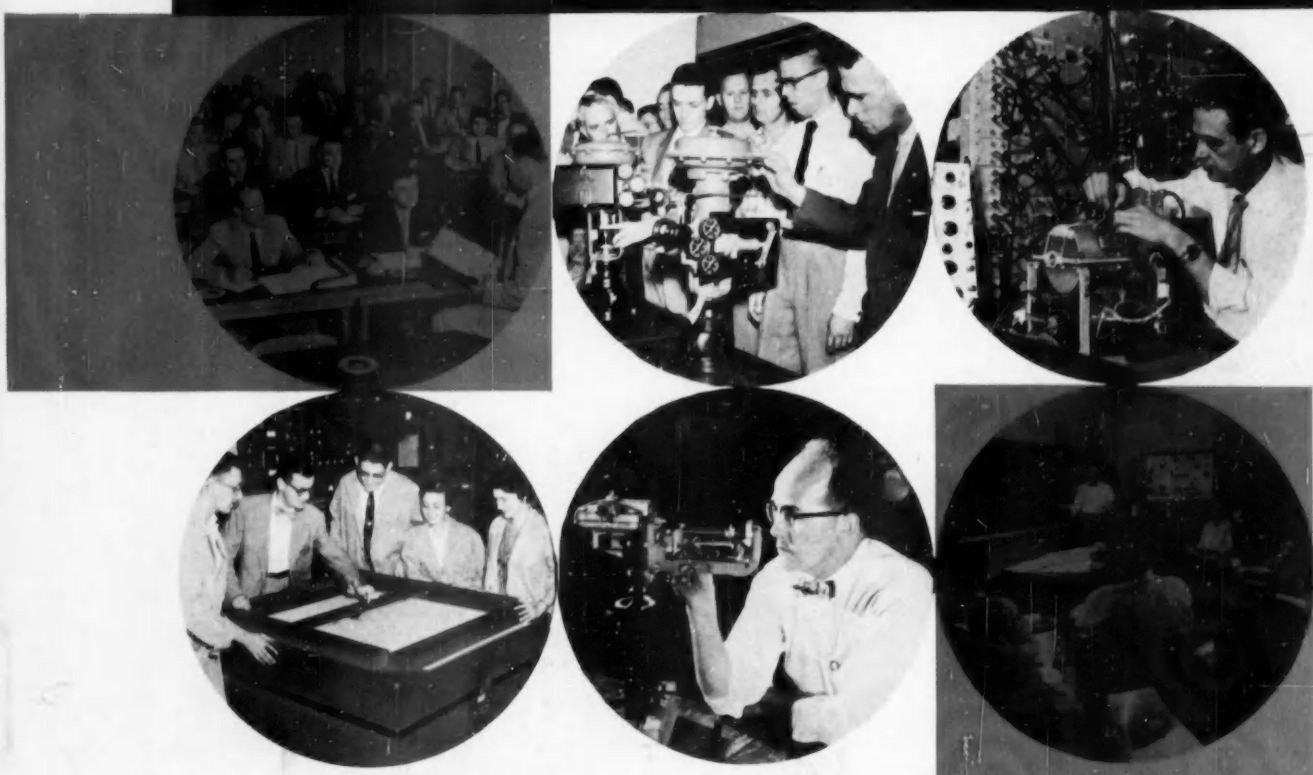
DECEMBER 1956



TRAINING FOR CONTROL



SPECIAL IN THIS ISSUE:

The Early Bird Goes Automatic

Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

DECEMBER 1956

ISSUE THEME

FEATURE ARTICLES

IDEAS AT WORK

DEPARTMENTS

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SHOPTALK

Training is Our Issue

The sea of faces poring over control hardware on our cover points out the theme of this issue: how our field is training its technicians. The face below—that of Editorial Assistant Frank McPartland—might well be tucked away in part of the assembly. For we recently sent Frank to join the ranks of trainees in control in a typical manufacturer training course (one of the 33 described in *Industry's Pulse*, page 55). To augment the cold facts in *Pulse* we asked Frank to write an informal report on how he fared at the school and what you—or your designated trainee—might look forward to if you also can break away from the job for some class work.

Frank's Report

In line with our current theme, the education and training of control personnel, I'd like to give our readers a few first-hand impressions of how one manufacturer, The Foxboro Co., is meeting today's demand for better trained instrument users. I say first-hand because I was fortunate enough to spend three weeks in July at one of Foxboro's general courses in instrumentation, largely due to the efforts of Chief Editor Bill Vannah and Harry Furry, director of training at Foxboro.

Although its own service and sales people are required, at one time or another, to attend these courses, Foxboro maintains the training center primarily to satisfy the educational needs of its customers. In addition to its general and special courses in instrumentation, the school sponsors each year a number of forums for various industrial groups. But the course most frequently offered, the one which best justifies the school's operating expenses, is the three-week General Industries Course.

Geared principally to the technician level, the course covers the fundamentals of industrial instrumentation and their practical application. Classes run from 8:30 a.m. to 5:00 p.m. daily. Actual test and calibration work in the laboratory amounts to about four days total time. Questions are welcome anytime during the classroom or bench-work sessions. Six well-qualified, full-time instructors, equipped with a raft of visual aids and working models, do a splendid job of maintaining student interest throughout the course. No examinations are given, but this seems to make little difference in the amount of "midnight oil" burned in the rooming houses nearby. Well-screened by their own companies, the students are mature enough to realize that laxity can hurt no one but themselves.

On Friday of the third week, there are no formal classes. Instead, there is a plant tour in the morning conducted by the school staff and there are conferences with industry consultants in the afternoon.

Probably the most enjoyable extra-curricular activity, aside from horseshoes at high noon, is the opportunity afforded each student to personally calibrate his own "appestat" at a dinner given for the "graduating class" sometime during the last week.

I'd like to take this opportunity now to thank Norman Anderson, Ken Bell, John Parkes, Gerry Bilyeu, and the many others in the school and in the plant who were so helpful to me during my brief stay at Foxboro.

FRANK McPARTLAND, Editorial Assistant

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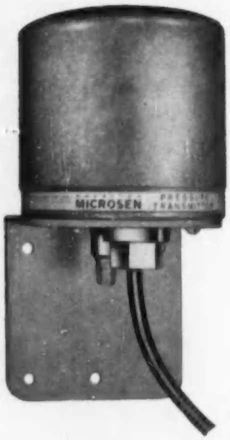
THE TRANSMITTER



The new Series 185 Pressure Transmitter is a miniaturized version of the well-known 'American-Microsen' Pressure Transmitter. It incorporates the latest mechanical and electrical features to achieve maximum operating benefits and usefulness.

The time-tested "Microsen" balance creates a stable dc signal for long distance transmission. Bearing pivots and linkages are entirely eliminated. Consequently, sensitivity is practically infinite, and repeatability of measurement is within 0.001% of range span.

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'American-Microsen' Transmitters of similar design are available for differential pressure, flow, temperature and other variables.

MANNING,

MAKERS OF 'AMERICAN-MICROSEN'

FEEDBACK

High School man wants in

To the Editor—

I am now a junior in high school and have become interested in a career in automation. Would you please send me what information you have regarding opportunities and education in the field.

Mike Schwager
Shoshone, Idaho

Check the following:
1. Dec. '56 issue of CtE
2. C. R. Otto, chairman of the ASME Instruments & Regulators Education Committee, E. I. du Pont de Nemours & Co., Inc., Louviers 33W8, Wilmington 98, Del.
3. J. C. Melcher, Instrument Society of America Education Committee, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia 44, Pa.

In view of the anticipated need for many more engineers in the control field, we must try to interest high school students. We propose a cross-society effort, perhaps coordinated by the American Society of Engineering Education, to prepare literature that will describe opportunities in the field. The sponsoring of this effort by the education committee of one of the professional groups in the field would be a most worthwhile project for 1957. Ed.

Information, please

To the Editor—

Your article "Six Industrial Users Size Up Automatic Data-Logging" in July was both interesting and enlightening.

It was especially helpful to us at

PROBLEM FORUM

What are the fundamental problems in measurement and control that need researching? The Interdepartmental Technical Committee on Servomechanisms of the British Ministry of Supply has attempted an answer, according to this letter from A. R. Aikman, Danbury, Conn.:

To the Editor—

I enclose a print of an article which appeared in the September '56 issue of the "Transactions of the Society of Instrument Technology" (published in England). Entitled "Outline of Research in Support of Control Engineering", it is interesting because it breaks down the whole field of control with official (Ministry of Supply) views on the need of research in each area of investigation listed. Note particularly that the committee which drew up the list "hopes to publish references" at a later date.

Surely it is significant that the British have described and classified measurement and control problems that require investigation. Equally revealing are reports from Americans who attended the Conference on Modern Theories of Control and Their Application this September at Heidelberg, Germany. (Ed. note: Reports by Rufus Oldenburger, Remus Bretoi, and Lowen Shearer appear on pages 32-34, this issue.) They make it clear that the Russians and Germans are doing very competent research in our field. Our current advantage over all of them is due to better products, greater know-how in applying them, and larger budgets for use of measurement and control equipment in both industrial plants and military weapons. But unless control engineers in this country can devote more time and money to investigation of fundamental problems, we can quickly fall behind.

• • •

Everyone can get into the act

Send us your detailed descriptions of fundamental problems that you think are getting insufficient attention. Your viewpoint will depend on whether your affiliation is with material processing, aircraft and ordnance, manufacture of machinery, or business operations. But you will see some problems in common. Our editorial staff will assemble, evaluate, and coordinate your responses for publication in CtE, presentation at national meetings, and discussion with government agencies. We offer cash prizes for the most thoughtful and most detailed studies.

If you would like a copy of the British outline for background, request one from The Secretary, Interdepartmental Technical Committee on Servomechanisms, Room 414, Shell Mex House, Strand, London, W.C. 2.

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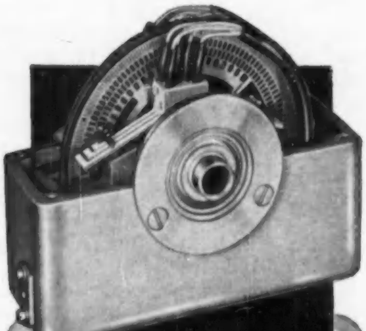

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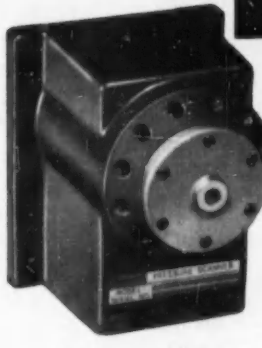


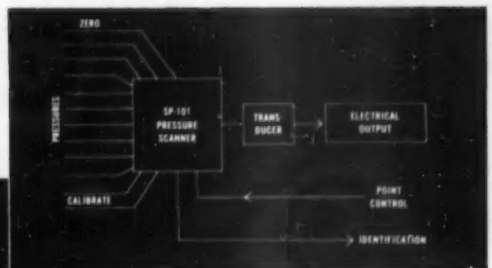
MODEL SP-101
PRICE **$395.00**

Designed to pneumatically switch a number of pressure sources into a single output port, the SP-101 Pressure Scanner introduces entirely new concepts into the field of pressure instrumentation. By providing an economical means of measuring a multitude of pressures, this device will accelerate the growth of automatic pressure recording in fields where it was heretofore economically unfeasible. Additionally, the pressure scanner not only reduces the number of transducers required for multiple pressure measurement but can be used to increase accuracy of measurement with presently available components. This is done by automatically introducing calibration and/or zero pressures during each recording cycle, permitting calculation of exact transducer response; and thus enabling greater measurement accuracy. Also, since the transducer is vented to atmosphere between pressure ports, hysteresis effects are minimized, contributing to greater measurement accuracy.

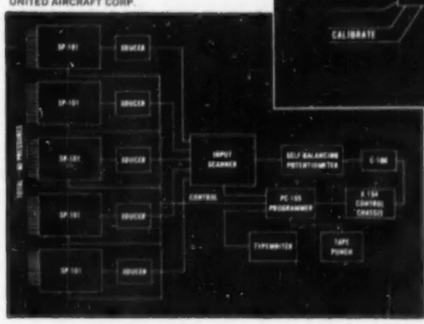
Basically, the SP-101 consists of a stator having 12 input ports, and a rotor that connects any one of the twelve input ports to an output port. The rotor is rotated to a desired position by a unidirectional high-torque motor, whose operation is controlled by means of a positive positioning arrangement. A relay circuit is incorporated in the unit to provide dynamic braking in order to stop the motor in a position where the rotor and stator ports are in coincidence.

The SP-101 Pressure Scanner can be used in applications that require the measurement of 12 pressures, all within the same transducer range. The unit can be externally programmed to switch pressures in any sequence desired, or it can be operated by means of a manual switch to select pressures to be measured.

TYPICAL SYSTEM USING ONE TRANSDUCER



*MANUFACTURED UNDER LICENSE FROM UNITED AIRCRAFT CORP.



Typical Datex Digital Data Recording System for Recording 60 Pressures

SPECIFICATIONS

FLUIDS: Air and non-corrosive dry gases
PRESSURES: From 0.1 psia to 350 psig
POWER: 50 watts, 115V a-c, 60 cycle
CONNECTIONS: Input and Output—1/8"NPT
POSITIONS: 12

Designed for bulkhead mounting.

For additional detailed information, write for Bulletin SP-101-1.

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this time as we are in the midst of making studies and preparations for a system or systems for our reactor test facility.

I would like to suggest that an article be published giving the types of systems (perhaps including block diagrams), the vendors, and where their operating systems are located. An article of this type would be extremely helpful in evaluating engineering proposals. I am especially interested in the system that Mr. R. L. Froemke described in the article and would like to know who prepared and installed the system.

The big question that management presents to the control engineers is "How reliable are automatic recording systems?" I am sure that an article such as that suggested would assist greatly in answering this question.

A. A. Simmons, Supervisor
Instrumentation & Control,
Naval Reactor Facility,
Westinghouse Atomic Power Div.,
Idaho Falls, Idaho

Your wish is our command. We have begun to accumulate descriptions of successfully operating automatic data-logging systems and hope to publish the requested article during the first quarter of 1957. Ed.

Merits better treatment

To the Editor—

I have received a rather violent objection to a book review published in the October issue of Control Engineering. This review was on the book *Random Processes in Automatic Control*, by Lanning and Battin. The published review, in the opinion of one of our young mathematicians, is written in a newsy fashion but is very glib, misleading, and very sketchy. The reviewer does not point out that much new material is covered in this book which has not been previously published. The review implies that the theory is applicable only to digital systems, and this is not correct.

In summary this reader feels that this is an excellent book and should have received a longer review pointing out its virtues.

E. M. Grabbe
La Canada, Calif.

We have invited Dr. Grabbe's "young mathematician" associate to review the book more thoroughly than did our first reviewer. Ed.

Expired patent belongs to all

To the Editor—

Pages 16-18 of the October 1956 issue of your publication carry a letter to the editor from Charles L. Kern, Sherman Oaks, Calif. As a patent attorney I would like to comment on this article.

The case that Mr. Kern attempts to make for inventions being "repatented" has absolutely no foundation in fact. It is axiomatic in the patent system of this country that once a patent has expired the invention covered thereby cannot be patented again. It is a fundamental, progressive, beneficial guarantee by the patent laws of our country that once a patent expires the invention covered thereby falls into the public domain *irretrievably*.

It is of course conceivable that the Patent Office, even with its staff of competent examiners, could overlook a pertinent reference in granting a patent. If this error occurs, the patent which issues is invalid.

A. L. Wade
Bailey Meter Co., Cleveland, Ohio

Systems are products, too

To the Editor—

Regarding the listening of CDC under "Consulting Engineers", page 92 of the September '56 Control Engineering issue—"Some of the Sources for Control Systems Engineering"—we wish to point out that we may have given an erroneous impression. CDC is not a consulting firm, but a designer and manufacturer of package control systems for aeronautical test facilities and continuous process industries. More specifically, we furnish Compu Dyne Control Systems . . . which use analog computer techniques to synthesize optimum configurations required for control of a dynamic and/or transient process. In our approach we use both analog and digital computer elements as field controllers and also use selected dynamic actuators and sensors to achieve large energy transfer with high control accuracy.

Perhaps your heading "Some of the Sources of Control Systems Engineering" should be "Sources of Control Systems". Obviously, the engineering required to produce a control system is much the same in magnitude, if greater in complexity, as that furnished by competent manufacturers. We all realize that application engineering is a necessary phase of the control field and never really

FEEDBACK

can be effectively isolated for the desired result, which is an optimum control system operating on-stream.

Sometimes our activity is confused with an engineering service because of the tremendous amount of systems engineering required for CDC to produce a control system package to extremely rigid dynamic specifications.

J. Lawrence Tecosky
CDC Control Services, Inc.
Hatboro, Pa.

Footnote to Industry's Pulse Survey of Control Manufacturer Schools . . . See page 55

Two groups of control manufacturing companies that responded to our survey were not included in the table. One consisted of those companies whose questionnaires came in after the Oct. 15 deadline, and the other of those companies with no formal training at present but with plans for a formal school or for an interesting informal customer training arrangement.

As of Oct. 25, the late respondees—those with established training schools—included Fielden Instrument Div. of Robertshaw-Fulton Controls Co.; Beckman Instruments, Inc.; Royal McBee Corp. (for Librascope computer).

Respondents that have no organized or formal customer training facility, but that do have informal programs for training technicians at the user site include: Allis-Chalmers Mfg. Co.; Benson-Lehner Corp.; B-I-F Industries; Link Aviation, Inc.; Mason-Nielan Div., Worthington Corp.; W. L. Maxson Corp.; Milton Roy Co.; Panellit, Inc. & Panellit Service Corp.

Companies with no formal program, but now in the throes of planning one: National Cash Register Corp.; Philbrick Associates, Inc.; Weston Instrument Corp.

To any user that wants more information on the training school facilities of the companies listed above, we suggest that it write direct to the firm's Training Director. If any maker not included in our survey would like CONTROL ENGINEERING to list its facilities please let Managing Editor Lloyd Slater know by letter. He will then send you a formal questionnaire. And if enough additional returns are assembled, a tabulation, similar to the one on pages 56-57, may be made in a future issue.—THE EDITORS

(ADVERTISEMENT)

A CONTROL PERSONALITY

BOB JEFFRIES
a catalyst for training

Robert Joseph Jeffries is never completely happy unless he's doing at least six things at once. In his 15 years as an educator and consultant he has tackled control field projects ranging from motor control through aeronautics to navigation and human engineering—often keeping to a schedule that would shame an election-year campaigner. A typical Jeffries' week: teaching at Michigan State, editing the *ISA Journal* in Pittsburgh, serving on a national committee in Washington, and spending a day each with clients in Chicago and Detroit.

Today, as assistant to the president of Daystrom, Inc., Jeffries still maintains his wonderfully varied, back-breaking pace. Catch him for a few minutes between flights and he'll enthusiastically tell you why. "I'm a flying catalyst. People are the most important ingredient in the future of our comany —and our technology. I'm making it my business to activate this ingredient—to launch and catalyze programs for training and developing the potentials of people. A catalyst has to be where the reactions are—not on a nice quiet shelf." (Ed. note: Jeff then stayed on the ground long enough to give us his views on educational needs—see Editorial, page 61.)

Start of the reaction

Bob Jeffries' career as a control catalyst began with EE and MS degrees from the University of Connecticut, which he sought with funds earned as a surveyor of the "fine terrain" of his native Connecticut, as a teacher of motor control and electronics, and as a summer employee of Pratt & Whitney. During the era of the V1's and V2's Jeff was at Langley Field with the NACA working on the development of its prototype missile tracking system and teaching extension engineering courses at nearby University of Virginia. In '48 Jeffries was awarded his doctorate in engineering by Johns Hopkins, where he taught electrical engineering and participated in a pioneer study of human dynamics in control—a subject which later became known as "human engineering". In the fall of '48 he went down to North Carolina State College, where he directed a pilot research installation of a long-range navigational system and taught automatic control (using the new Brown and Campbell text).

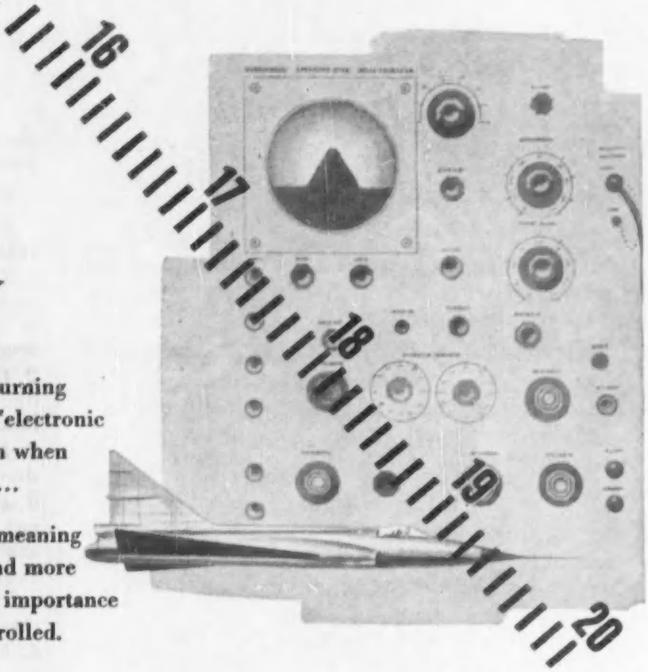
In 1953, during his fourth year as an associate professor of electrical engineering at Michigan State, specializing in automatic control, Jeffries, then chairman of the ISA Education Committee, organized the first national industry-government-university meeting devoted to educational problems posed by the new technology. Meanwhile he was editing the newly founded *ISA Journal* and squeezing out hours for consulting to industry on problems of control, system design, and education. Soon he and two associates formalized their consulting practice in Educational & Technical Consultants, Inc.—a service which draws on the talents of specialists in 73 colleges. One of his clients, Schlumberger Well Surveying Corp., took a cue from his report and formed Schlumberger Instrument Co., bringing in Jeff as technical planning advisor to President Henri-Georges Doll (CtE, Dec. '55, p. 15). Upon completing his phase of the work last spring he went to Daystrom as assistant to President Thomas Roy Jones.

In a press conference prior to the recent ISA national meeting, Jeff, flanked by other leaders in his field, proudly announces the establishment of a Foundation for Instrumentation, Education & Research by the Society (see page 61).*

At 33, Bob Jeffries is only at the start of a remarkable career, but he sees no reason to pace himself. "Education is a long-term, continuing proposition," he reminds us, "but it never gets off the ground without dedicated effort." Jeff's attractive wife Anna and his two children have grown to accept his time away from home that such dedication requires. "But," says Anna philosophically, "I'm looking forward to the day when Jeff becomes president of ISA (now president-elect secretary, he'll be president in 1957-8) because I will then at least be able to keep up with his activities through the *ISA Journal*."

*L to r: John Johnston, du Pont; John Ragazzini, Columbia U.; Elmer Engstrom, RCA; Robert Sheen, Milton Roy Co.

SECOND OF A SERIES



How to get reliability

Got the automation jitters?...worried about turning complex manufacturing operations over to an "electronic brain"?...worried about what can happen when one component in the control system fails?...

Reliability takes on a new and different meaning as American industry becomes more and more automated. Here are a few thoughts on the importance of reliability and how it can be controlled.

All of us are going to have to pay more attention to "reliability."

We'll have to pay more attention to individual "devices" within a system.

We'll have to guard ourselves carefully when we design the entire system.

The industrial pendulum is swinging more and more toward automatic controls, servo-mechanisms, computers, and automatic "watchers." As it does, the reliability factor becomes more and more important. Let's see why. For example, you probably have three radios at home. If one fails because a soldered joint comes apart, your home life is probably not disrupted to any alarming degree. But... consider the automatically controlled steel mill. One soldered joint failing, unless all controls are installed in duplicate (which is expensive) could tie up the entire production process for valuable minutes, if the maintenance crew has second sight. For hours, if automatic trouble-indicating and locating systems are not installed (and these are expensive, too). Last, but not least, lend a thought to the dependence of guided missiles and man-made satellites upon the reliability of electronic circuits and components. So... let's start to examine "reliability." Let's begin by looking at this definition which is currently popular in the technical field:

The reliability of a particular component or system of components is the probability that it will do what it is supposed to do under operating conditions for a specified operating time.

Now...this is a relatively well-accepted definition, and it offers the key to the problem of coping with failure control. Take the word "probability" in this definition. Let's discuss its implication.

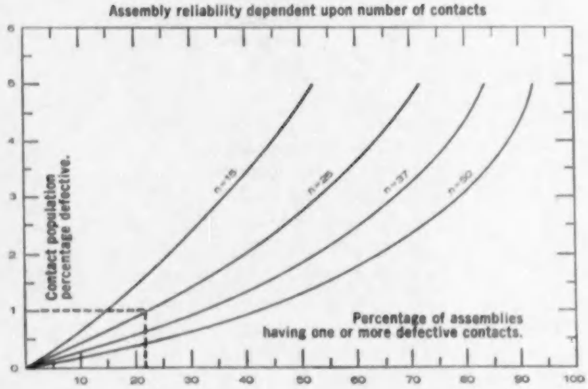
Many of today's systems, simple or complex, are a chain of components. So picture a system as a chain with its successive links. In the field of statistics the over-all reliability of the chain is the mathematical product of the reliabilities of the individual links...

Overall Reliability, $R_o = r_1 \times r_2 \times r_3 \ldots r_n$

Now, let's consider a system made up of 100 different components, each of which has a reliability of 99%. In applying the formula, multiplication of .99 by itself 100 times gives an over-all reliability for the system of only 36.5%. Two out of three systems you have put together will probably fail!

Cannon becomes involved with this problem because our main business is making electric connectors. So, let's look at the following chart that covers contact reliabilities and reliability of the assembly in which they are mounted.

Assembly reliability dependent upon number of contacts



This chart illustrates the reliability of four connectors having 15, 25, 37 and 50 contacts respectively. As an example, assume that the contacts have a contact population of 1% defective (1 in 100 defective ... this percentage is considered a fairly high standard in most fields). On the 15-contact assembly, we find from our chart that 14% of the connector assemblies would have one or more defective contacts! With 25 contacts, 22% would have one or more defective contacts. With 50 contacts, 41½% ... is your hair starting to curl? Obviously, a 99% contact reliability standard for guided missile components is absolutely unacceptable. And, in between the simplest system and that of a guided missile, are hundreds of assemblies and systems whose reliability factors must be analyzed with utmost care.

But all is not lost! There's another side to the picture. With proper care, analysis, and control, our Cannon organization has actually achieved, in special "missile quality" contacts, a known level of only $2.85 \times 10^{-3}\%$ defective ... only 1 part in 35,000! Naturally, we don't achieve that with all our contacts ... but we do try to design and manufacture the utmost in reliability required for specific applications.

We have pictured this chart to show the direction we must all take, whether we're talking about connectors, other components, or systems. It boils down to two steps ...

- ✱ The number (n) of components must be kept low ... *simplicity.*
- ✱ The level of component reliability must constantly be improved ... *hard work for all of us.*

Now ... if we refer to our reliability definition on the previous page we note the phrase "do what it is supposed to do." So be sure *you* define these objectives for your component assembly, or system ... failure to do so carefully can cause undue failure or the expenditure of unnecessary dollars for needless, excessively-reliable parts or design.

Further on in the same definition, we note the words "operating conditions." This brings up many new points for consideration. Here we are concerned with such things as temperature, pressure, humidity, corrosive atmosphere, stray electric and magnetic fields, low and high frequency noise, shock and vibration. Do your design standards need upgrading? Are your components designed and then tested to meet the operating conditions you specify ... or are they designed to meet "average" conditions? Are you using adequate "safety factors"?

In a simple component, manufacturers have always looked for, recognized, and corrected faults when they occurred. We use component quality control to achieve and maintain Cannon's world famous product quality. But in complex systems such component quality control is not enough. Actually ...

Reliability control over the system is needed. It should be all-encompassing. When you get right down to it, *reliability* is the product of procedures, equipment, and people ... in the design, manufacture, testing, control of quality, transportation, and use of products or systems.

Do you have a reliability control system?

Here are a few of the steps that are needed to get a reliability control system operating:

1. Determine Your Requirements. Specify the environment, operating time, performance limits, and the percent of reliability required. Allow an adequate safety factor keeping in mind the end use of the finished product.

2. Collect Reliability Data. Set up facilities for the continuous accumulation of data on component or system failures and their causes.

3. Establish quality control and test procedures which show high degree of correlation with end-use conditions.

4. Analyze. Determine if reliability requirements are being met. Establish the most important causes of failure by analyzing the data you collect.

5. Improve. Take action to eliminate the most important defects or causes of failure. Reduce the failure rate to the required level.

6. Maintain Continuous Vigilance. You have emphasized system design ... you have used statistical analysis of failures ... now exert continuous and critical control to be sure your "improvements" actually improve reliability. Examine new and unforeseen failure sources. Review and modify your requirements with changing conditions.

✱

We at Cannon Electric are proud of our historical emphasis on quality and reliability. Since 1915 we have adhered to a design philosophy embracing the highest quality and reliability in each and every Cannon Plug for the specific application for which it is to be used. *If we can't design to that principle, we don't make it!* In manufacture, we are proud of our know-how in depth, proud of our fine quality control systems, proud of our personnel and proud of our reliability control group.

Whenever *you* have an electric connector reliability problem ... in design, engineering, production, or prototype phases ... we would appreciate the opportunity of discussing it with you.

Cordially,

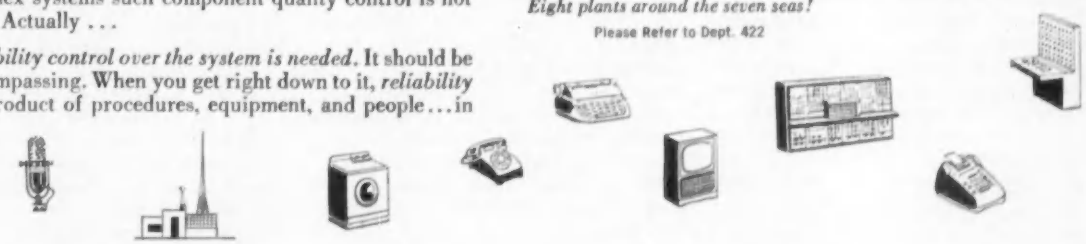
Robert J Cannon *President*

CANNON ELECTRIC COMPANY
3208 Humboldt St., Los Angeles 31, California

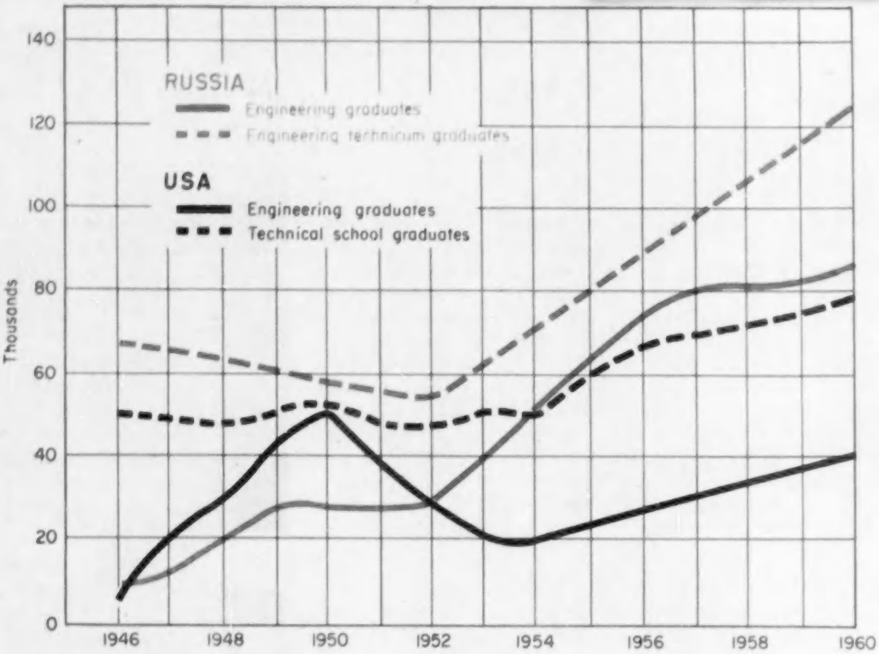
CANNON PLUGS

Eight plants around the seven seas!

Please Refer to Dept. 422



How Two Nations Are Training for Control



U.S. Steps Up Its Technician: Engineer Ratio

- ▶ through society activities
- ▶ by emphasis in schools
- ▶ with more manufacturer training

The graph above* dramatizes an aspect of engineering manpower that is often overlooked in today's frenzied search for qualified engineers: the importance of the qualified technician in backing up the engineer—and thus contributing to the solution of the current "shortage".

Study the graph and see what is happening to the technician gap in the United States' most important engineering competitor. Since 1952 the Soviet Union, observing a decline in its technicians due to emphasis on professional education, has put steam into a program for getting more graduates from its "technicums", or semi-professional schools. The goal set for '55—a 35 percent increase in technicians over the 1950 level—was exceeded, and it is now estimated that Russia's 3,500 technicums are turning out close to 1 million vocationally trained people each year. The dashed red line in the graph indicates roughly 100,000 technicum graduates in 1956, but it covers only the engineering technicians turned out by these schools. The dashed black line for the U. S., however, represents the enrollments in 69 technical institutes and includes all types of vocational training.

*SOURCES:
On engineering and Soviet technicum graduates—estimates from Nicholas De Witt, *Soviet Professional Manpower*; on U. S. technical school graduates—*Annual Surveys of Technical Institutes*, Rochester Institute of Technology.

The optimum ratio

An important key to its attitude toward technician training lies in what Russia calls its optimum ratio between semi-professionals and professionals. In pre-war days the ratio was less than a desired 2:1. and declined by 1950 to only 1.3 technicians to back up each engineer. Today the aim in Russia's automatic control field is four technicians for each professional engineer—and all signs point to fulfillment of this aim.

Many American industrial firms are also aware of this need for an optimum ratio between technicians and engineers. E. Allan Williford, president of Link Aviation, says, "We have approximately 120 graduate engineers at Link. We also have about 160 trained technicians, not nearly enough. We probably should have a ratio of at least three technicians to every engineer. Any lower ratio simply means that we're not getting maximum value from our engineers . . ." Some other ratios:

- ▶ Westinghouse Electric, Air Arm Div.—two technicians to one engineer
- ▶ Standard Oil of Indiana—1.9 technicians for each engineer
- ▶ U. S. Steel Co., American Bridge Div.—800 technicians, 700 engineers

Not all companies, however, match the ratios above. A survey by the Engineering Manpower Commission of 18 oil and chemical companies, for example, showed an average 0.9 technicians per chemical engineer.

Why stress the ratio?

As Bob Jeffries implies in his guest editorial on page 61, a lack of emphasis in training technicians for automatic control can result in two things:

1—Our dedicated efforts to put automatic control in American industry can come to a grinding halt—technicians are needed to keep operating what is placed in the field—it is as simple as that.

2—Our so-called engineering manpower shortage will never be solved—without technicians, creative engineers will bog down in a mass of routine, time-consuming operational and design details.

It is the second point that is start-

(*Continued on page 20*)

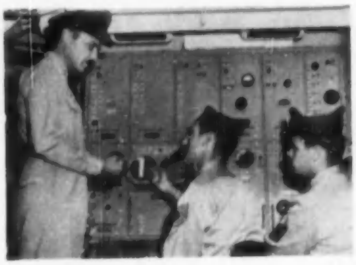
HOW THE U.S. IS DOING IT IN THE CONTROL FIELD . . .

. . . Through society activity

The picture on the right records a historical moment in technical society efforts toward solving the trained manpower shortage in the field of automatic control. Dr. Bob Jeffries (see *Control Personality*, page 15, to identify his colleagues) is announcing, at a press meeting prior to the recent ISA Show, that the society has established a nonprofit Foundation for Instrumentation Education & Research. Launched with an initial grant of $40,000, the Foundation will give specific attention to: a) training industry and its personnel in fundamentals; b) updating schools and colleges; c) attracting young people into the field; d) translating research findings into industrial language and practice. For more on technical society activities in helping to step up the technician engineer ratio . . . SEE PAGE 20.

. . . By emphasis in schools

On the far right Sperry Gyroscope's chief engineer, Dr. Lisle L. Wheeler, briefs Philip Becker (left), assistant superintendent of New York City schools, and William Fenninger, chief of New York State's technical and vocational education, on the problems in maintaining automatic compass equipment in cold weather. The demonstration, which took place on Oct. 16, was part of a day-long discussion between educators and Sperry executives to determine how state and city high schools might revise courses to meet industry's expanding needs for technicians. Similar meetings have been held in the past by the New York educators with local industry (i.e., Bell Telephone, Western Electric, IBM) to assay the special skills required to equip young people for the job of maintaining and operating automatic systems. For more . . . SEE PAGE 28.



. . . With more manufacturer training

Pictured above are facilities of three of the 33 control manufacturer training schools described in detail in this month's *Industry Pulse* (see page 55). On the left are part of the sizable bench equipment in Minneapolis-Honeywell's long established (25 years) industrial instrument training school in Philadelphia. In the center, military technicians are instructed in the operation of Reeves Instrument Corp. analog computing equipment in the New York schoolrooms of Dynamics Corp. of America. On the right an ElectroData instructor takes a group of "students" into the digital intricacies of the equipment manufactured by this Burroughs Corp. division. The latter locale: Pasadena, Calif.

As *Pulse* this month indicates, the locales for these training centers for control are as widespread as the control manufacturing industry itself. In almost all cases the tuition is free and all that a control-user company need do to enter a selected man is write a letter. A short plane ride, a week or two away, and your man comes home—trained for his job.

Free training by American industry—particularly in the control field—is a unique phenomenon, unmatched anywhere else in the world. To industry's schools each year come young technicians from India, free China, Peru, and Israel . . . and close to 100,000 American control trainees. The upshot is a dynamic educational program—borne at considerable expense by the control maker—that undoubtedly accounts for the rather unbelievable dependency that industry already has on measuring instruments, automatic control devices, and systems. For a close-up on how the control makers will train your technicians . . . SEE PAGE 65.

ing to preoccupy today's engineering manager and may be the real prime-mover for getting technician training in the U. S. well off the ground. Bidding next June for an estimated 23,000 engineering graduates will be over 5,000 companies—which means that less than five new recruits will be available per firm. Yet most expanding industrial firms today claim they need new engineers by the scores, even hundreds. An answer, they are finding, is to use the trained technician for some staff engineering jobs and to upgrade him, if necessary, to full engineer status. This is causing industrial recruiters to include technical institutes in their itineraries and is causing companies like Carbide & Carbon (see page 65) to emphasize the engineering apprentice approach in its on-the-job training program.

Organized ratio boosters

Though it lags notoriously right now, the U. S. has high hopes for matching and besting the Soviet Union's remarkable technician training program. For while both bank heavily on formal schooling plus some on-job training, the U. S. has in addition to these sources, two other prime-movers: 1) the engineering societies, with their focus on lower-echelon education; 2) the product manufacturers, with their free schools for training customer technicians.

The next five pages of *What's New* offer a current glimpse of some of these forces at work in the training of American technicians for control.

In ISA Session on manpower training Paul Huss, University of Akron, claimed that enrollment in secondary school technical courses is on downgrade.

ISA Works for Technicians

Progress in product and technique may have been the theme at the recent 11th annual Instrument Society of America conclave (see November issue, pp. 25-40), but there was one problem in the minds of the membership that threatened to overshadow it: the problem of producing the properly qualified technicians needed to service and run the new installations.

The problem did not simply fester in the minds of ISA members, however. They did something about it. Besides conducting training clinics (CtE, Nov., pp. 38-39), the ISA—

- ▶announced an Education Foundation with funds to attack the technician shortage problem (see page 61)
- ▶conducted a symposium on ways and means to increase the training of manpower in instrumentation
- ▶held an Education Committee meeting on the day following the symposium to mull over possible action based on what was learned
- ▶cooperated with CONTROL ENGINEERING in a display of work being done in the control field by eight education institutions.

The ISA's new Foundation for Education & Research will function as a separate corporation under the direction of a board of trustees drawn from industry, government, and education. While its initial grant of $40,000 is from the society itself, it hopes to be financed through funds supplied by individuals, other technical associations, and industrial contributors. It will be housed at first in the ISA headquarters in Pittsburgh. Bill Kushnick will serve as executive director (a post

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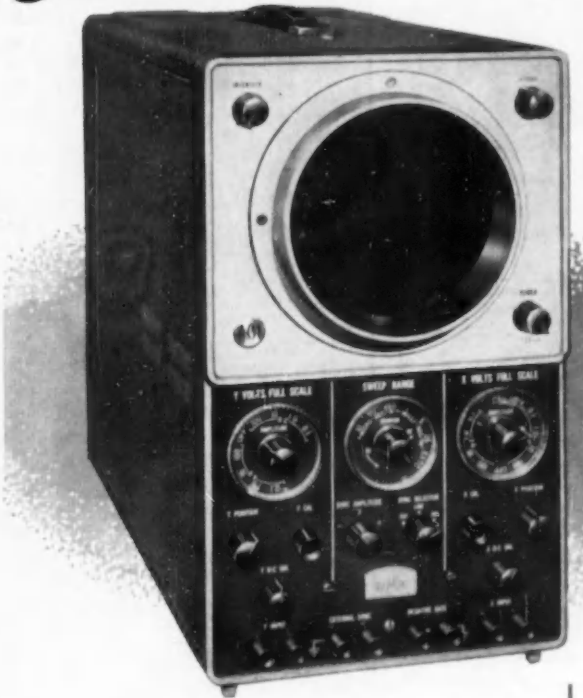

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he now holds, and will continue to hold in ISA).

At the symposium

Four of the five papers offered during the special Education Symposium on Tuesday, Sept. 18, concentrated on the problem of developing instrument and control technicians. Foxboro's W. H. Furry complained that instrument technicians are too often categorized with bricklayers and carpenters—almost invariably by unions and frequently by management. He called for abolishment of the term "instrument mechanic" and said that the status of technicians could be raised by placing them on salary and thereby removing them from union jurisdiction. The body of his talk was about technician training, which he wants formalized. His three part method: learning the *why* of instrument operation; showing the man *what* to do and *how* to do it; making him practice until management is sure he can do it.

Paul Huss of the University of Akron gave an impassioned plea for more emphasis on the role of the secondary school in expanding technical manpower. He felt that the humanities were being stressed too much and that more interest on a broader science-and-mathematics base could be stimulated by such things as good science films at the junior high level. He advocated "pushing the people who could become good engineers or technicians" but was "opposed to regimentation". Mr. Huss didn't quite tell the audience how to do the necessary pushing.

Chapter activities

The final paper in the Education Symposium, by A. T. Sherman of du Pont, dealt with "Instrument Courses Sponsored by ISA Chapters and Instrument Manufacturers". Sherman briefly discussed the results of a survey that went to 57 instrument makers and the 76 ISA chapters. Of 20 chapters replying, eight had a program of some sort—either organized and run by the chapter, or taught at a local university.

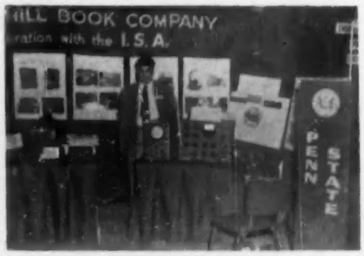
The good work that ISA chapters are performing in training technicians has been reported before. In 1954 R. J. McCausey of Detroit Edison found that 10 chapters conducted 37 training courses in '52 and '53, and that these were attended by 596 individuals. One of the best organized of these courses was run by the Boston Section. It was advertised as an "instrument technician refresher course,"

ran for five weeks (2½ hours per week), and cost \$3. A total of 82 attended, and as a result of enthusiastic answers to its questionnaire, similar courses became standard activity for the Boston Section.

University activities

Educational activities at the college level were brought out during the ISA show in a special exhibit (see pictures below) of instrument and control development projects in eight eastern universities cosponsored by CONTROL

THE UNIVERSITY EXHIBITS



Penn State

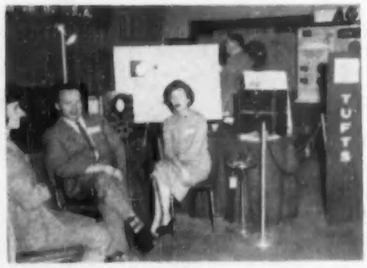
RPI

Yale

Cornell

WHAT'S NEW

MIT



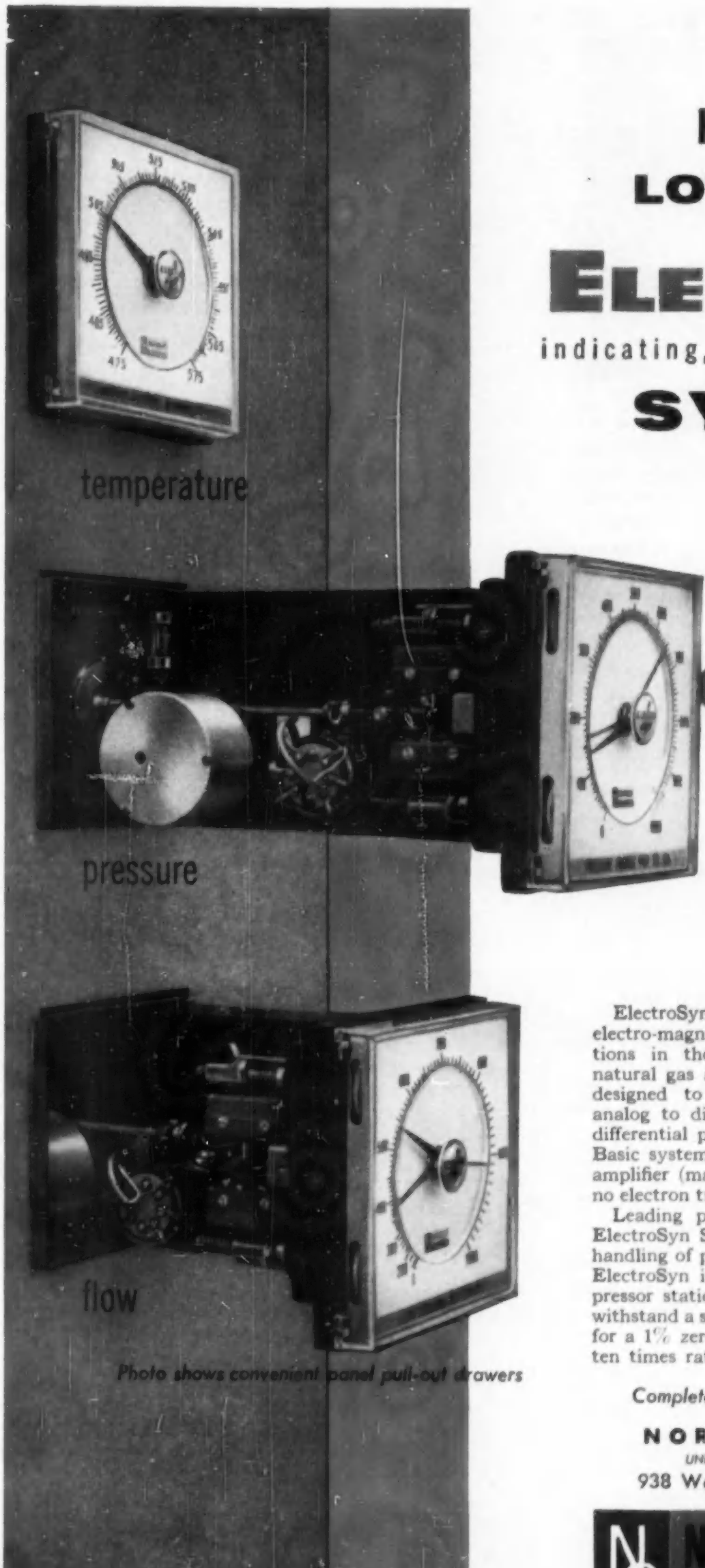
Tufts

Johns Hopkins

Princeton

ENGINEERING and ISA. Manning the exhibits were graduate students and faculty members associated with the conception and design of the prototype systems on display (see CtE, Sept. 1956, pp. 185-192, for details on some of the projects).

Eight of the faculty members connected with the exhibit (picture next page) met in a formal session Tuesday morning, Sept. 18, to discuss their respective projects and educational programs in control. Managing Editor Lloyd Slater, who served as re-



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ISA-McGRAW-HILL UNIVERSITY PANEL

Members, standing (l to r): P. Clement, Princeton; J. Gibson, Yale; R. Phelan, Cornell; J. Reswick, MIT; E. MacNichol, Johns Hopkins; A. Slocumbe, Tufts; H. Dimant, Penn State; seated (l to r): W. McClintock, RPI; B. McKay, U. of Tenn. (chairman); L. Slater, Control Engineering (recorder).

corder at this session, reports, "The interchange of ideas in this group was extremely interesting. Three of the men were medical-instrument oriented, three were outright theoretical control engineers, and the other two dealt in physics and mechanical engineering. Yet all were able to develop provocative comments about each other's project. For example, Dr. Slocumbe of Tufts became very intrigued with Jim Reswick's nonupset technique for systems analysis and planned to team up with Jim in a study of the 'dynamics' of a rat under automatic anesthesia. McClintock of RPI, on the other hand, enthusiastically saw his time-modulated six-count tape recorder as a tool in the servo analysis projects at three of the schools."

Educators Focus on the Technician Shortage

New York's roving team of education administrators, described in a visit to Sperry Gyroscope Co. on page 19, furnishes vivid proof that action is accompanying the intense soul-searching going on in American public school education today. In attempting to meet industry's plea for more technically trained youngsters, the educators find themselves compelled to seek answers to the kind of questions posed by Dorothy Thompson in a recent column. Why do, she asked—

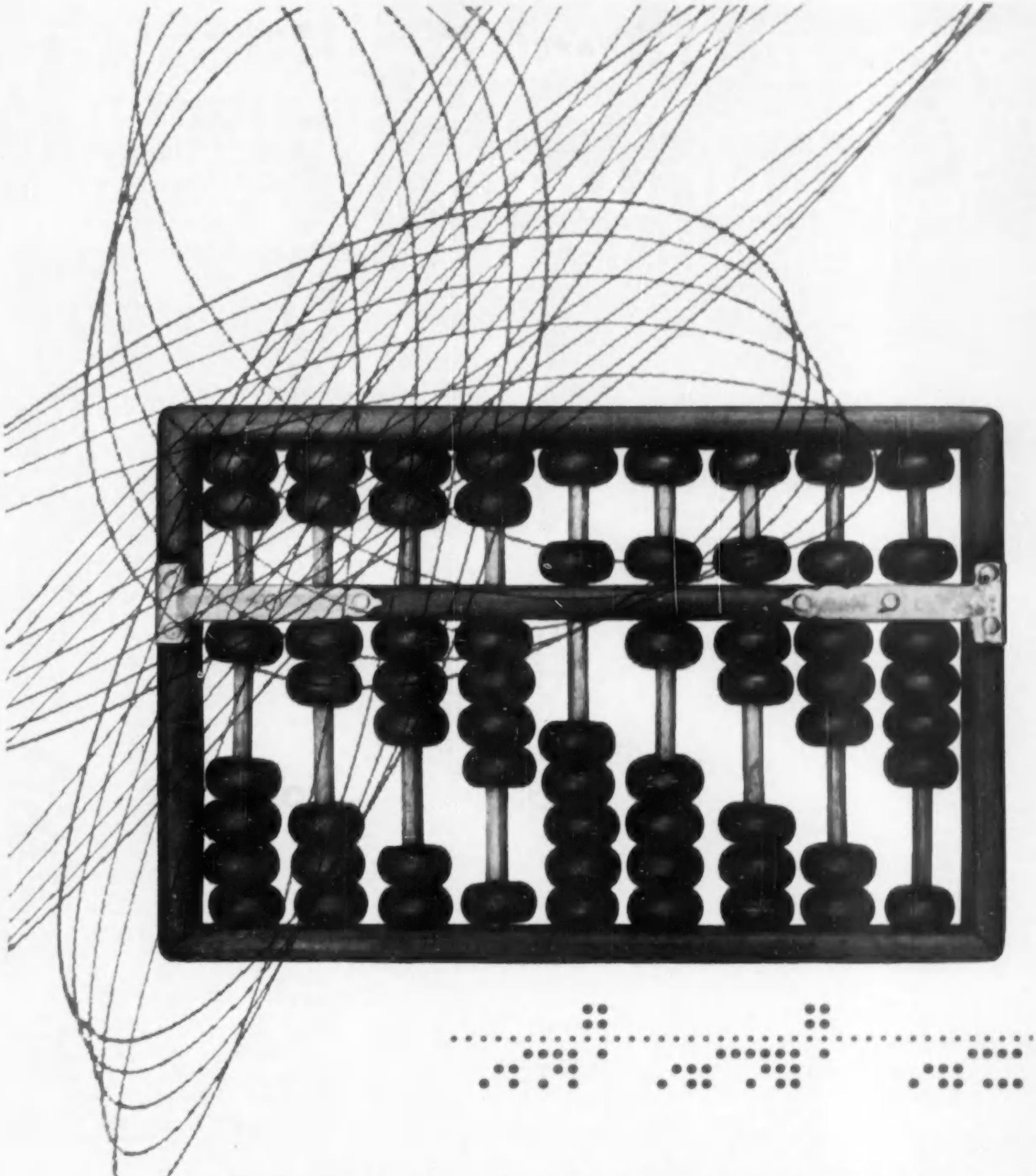
▶ only four percent of American high school students study elementary physics?

▶ only seven percent study chemistry, 27 percent algebra, and 13 percent geometry?

▶ only half our schools offer courses in chemistry and physics?

Nathan Clark, supervisor of technical subjects, New York City Board of Education, and a member of the team of visiting educators, feels the need for a concerted effort by both industry and state and local education authorities. "There are countless American children entering high school," points out Clark, "with IQ's of 105 or over who could make very capable technicians or engineers. In our vocational program we have found we can give these students a full four years of math and four years of science. Further, our laboratory work gets the student's hands busy with electronic and industrial devices, as well as his mind into the basic theory behind such equipment. Then when the boys and girls graduate they are literally conditioned for industry—and are happy and interested in the jobs they get." Mr Clark goes on to point out that this "industrial conditioning" is often lacking in most technical schooling—even colleges. "Why do 50 percent of graduating engineers drop this field in their first five years out in industry?" he asks.

Supervisor Clark is very enthusiastic about the New York Board's program of meetings with industry to determine what the latter needs in the way of special training in vocational school graduates. In the get-together with



Sperry, for example, observation of Sperry technicians at work suggested some mild adjustments in the courses offered in five New York technical high schools. After it reviews the suggested adjustments, the group will confer with Sperry again.

Stepping up training

New York City, advises Clark, is now embarked on a stepped-up plan for technical education. "We are working out better ways to select students and are determining what schools can best be set up for technical education." But city programs are relatively easy, he comments. "Other, smaller communities have a great problem in getting the necessary funds to train or hire the proper type of teacher for technical education. Engineers are needed–hence the community must compete with local industry. It seems to me that industry, in order to satisfy its larger, broader need for technicians and engineers, must get behind a local movement for higher starting salaries to entice teacher-engineers into nearby schools. From these schools will come the technicians they need so badly."

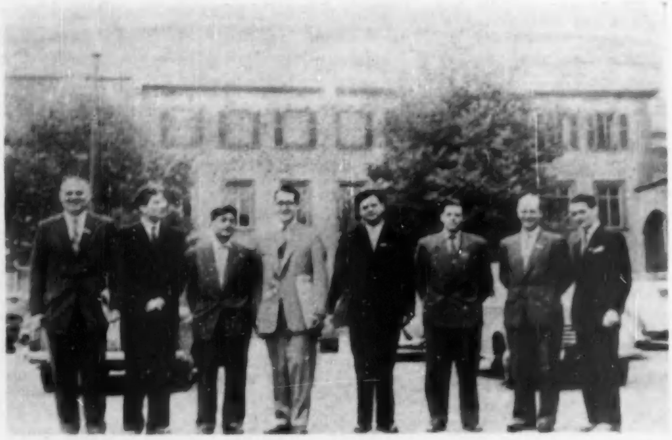
Industrial leaders, increasingly aware of the technician shortage and the potential for technician relief of the more difficult professional engineer problem, are starting to echo Nathan Clark's sentiments. The Thomas A. Edison Foundation meeting at West Orange, N. J., Nov. 19-20, and the Joint Program for Technical Education of the Columbia School of Engineering, which held a session at Arden house, Harriman, N. Y., Oct. 30-Nov. 2, brought together educators and industrialists to discuss what draws young people to technology and how our colleges can help the hard-pressed science departments of high schools. These are but two of the many meetings throughout the land that are approaching the so-called engineering shortage problem in this new direction: through renewed, rebuilt emphasis on technology in secondary education.

Ed. note: The report above on increased activity by educators in technician training does not include the important area covered by the post-high-school technical institute. Many schools in this category have added, in the past few years, special courses in instrumentation and control. We hope to survey these courses and perhaps come up with an *Industry's Pulse* (similar to the one this month) that will tabulate the information.

WHAT'S NEW

Heidelberg Gives Control International Stature

A special contribution from R. N. BRETOI, Minneapolis Honeywell Regulator Co., and RUFUS OLDENBURGER, Purdue University —based on their observations at the recent control conference in Heidelberg, Germany.



CONTROL INTERNATIONALISTS: Intense interest in the same subject dissolved national barriers at Heidelberg. This typical group includes: (l to r) T. A. Buchold, GE; A. M. Letov and Ya. S. Tsypkin, U. S. S. R; H. Chestnut, GE; B. N. Naumov and V. A. Ratchejev, U. S. S. R; R. Oldenbourg, Germany (publisher of *Regelungstechnik* magazine); Russian interpreter.

An international automatic control meeting called Tagung Regelungstechnik, sponsored by VDI (Verein Deutscher Ingenieure) and VDE (Verband Deutscher Elektrotechniker) was held at the University of Heidelberg Sept. 25-29. Over 900–250 from outside of Germany–registered for the meeting, which was organized by the VDI-VDE control committee under the guidance of its secretary, Dr. G. Ruppel. The VDI, with 32,000 members, and the VDE, with 20,000 members, correspond to America's ASME and AIEE.

At the initial session, which was attended by 1,000 people, the rector of the university introduced Dr. O. Grebe who, as general chairman, officially opened the meeting. He was followed by representatives of the U. S. and U.S.S.R., who brought their respective greetings from the ASME and the Institute of Automatics & Telemechanics in Moscow. The session continued with general lectures on the theme of the meeting (mathematical methods in the design of automatic control) by J. L. M. Janssen of Holland and Rufus Oldenburger of the U. S.

BANQUET MIT DAMEN: This view of the speakers' table at the final dinner indicates that many fraus also took the opportunity to visit the lovely old university town of Heidelberg. In the foreground is the wife of Prof. G. Evangelisti of the U. of Bologna; to her right Mrs. R. N. Bretoi; across the table the wife of Prof. L. V. Hamos, Kungl. Tekniska Högskolan, Sweden.

The final paper in the opening session, written by W. A. Trapeznikov and B. J. Kogan and read by Prof. A. M. Letev, editor of the Russian *Journal of Automatics and Telemechanics*, was devoted to the use of electronic analogs of controlled systems. It pointed out that multiplication, generally performed by using the formula

$$xy = \tfrac{1}{4} (x + y)^2 - (x - y)^2$$

gives poor results when the factors are near zero, and has been superseded in the United States by better methods involving areas.

Around the control curtain

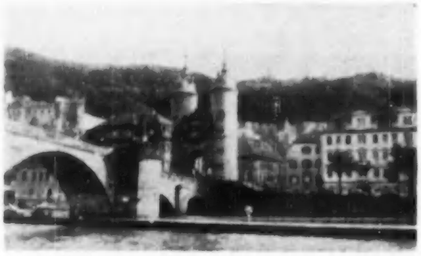
Sixteen men from the United States and four from Russia (see picture above) came to the meeting. Lectures by the latter were promptly translated from Russian into German by the interpreter who accompanied them to Heidelberg. Representatives from East Germany, Poland, and Czechoslovakia were also present in force. It was apparent that the control experts from these countries were eager to establish contacts with western colleagues. They expressed the hope that these contacts, besides facilitating scientific interchange between east and west, would increase the chances for world peace.

About 20 German control engineers, sentenced after the war to five-year work terms in Russia, were also at the meeting. While in Russia they were paid twice as much as their Soviet counterparts, but were confined to living and working quarters and could only leave with official permission in groups of ten, with three Russians in each group. Some of the ex-prisoners at the meeting were rocket control specialists. They made the amazing disclosure with respect to their work in Russia that they were able to obtain all the western literature they needed, while much of the Russian material was available only to Soviet engineers. All of the former prisoners spoke Russian and were of great assistance as translators at the meeting.

The 63 papers were presented in French, Russian, English, and German and covered all major areas of automatic control. Means for decoupling multiple-loop controls with the aid of matrices, frequency response, nonlinear systems, the use of statistical methods in minimizing errors and determining transfer functions, means for optimizing controls (with various definitions of "optimum"), analogies between stochastic and dynamic processes, and the use of computers were treated. There was much emphasis on nonlinear control systems: 11 papers by authors from seven countries were devoted to this

DAMPFERFAHRT AUF DEM NECKAR: One of the conference highlights was a boatride Sept. 29 down the Neckar river to Neckarsteinach. Identifiable in this group are A. M. Letov (right), Ya. S. Tsypkin (in front of flag,) and R. Oldenbourg (on Tsypkin's right). Two days of tours to German business establishments and factories were also part of the program.

DER DISKUSSIONEN: The technical sessions took place inside this building at University of Heidelberg.



DES SCHLOSSES: Perched high on the hill above the old bridge is the 600-year-old castle where banquet and fireworks were held.

subject. Ten of the papers were seriously concerned with the statistical approach.

The work of the Russian participants concerned optimum sampled-data systems, means for calculating nonlinear control systems, stability criteria, the self-adjustment of parameters for the optimum performance of a system subject to random disturbances, and structurally (inherently) unstable systems. Contributors were members of the Moscow Institute of Automatics & Telemechanics, which is actively engaged in developing control theory. Although the Soviet Union is graduating 5,000 control engineers a year, the contact between theory and practice in that country does not seem to be as direct as in the United States.

Theory put to work

Many of the papers dealt with the application of theory to such physical problems as the control of steam generators, water turbines, and diesel engines, the charging of storage batteries, the automatic longitudinal control of aircraft, the regulation of electric arc furnace impedance, the control of machine tools, and the regulation of temperature. It is clear from these papers that much of automatic control theory finds immediate application in industry both here and overseas.

L. S. Dzung of Switzerland showed that the controls in multiple-control systems could be uncoupled using the reciprocal of the transfer matrix of the plant. He applied this to an extraction steam turbine. A. Nomote of Japan pointed out advantages of log root-locus plots. K. Izawa and S. Hayashibe, also of Japan, surveyed criteria for good general response and concluded that gains and phase margins of at least 3 db and 20 deg for processes and 12 db and 40 deg for servomechanisms are desirable. Erick Bkovics of Austria, who examined the ease with which stability criteria can be put on digital computers, declared that the Routh and Leonhard-Cremer criteria are well suited for this purpose.

E. G. C. Burt of England and V. V. Solodovnikov of Russia gave papers on the self-adjustment of controlled systems to give optimum performance for nonstationary random disturbances. Solodovnikov also treated stationary random processes in some detail. J. H. Westcott of Great Britain considered processes that need controllers for satisfactory results. If it is not possible, he said, to record supply and load disturbances directly, the dynamic characteristics of process and controller can come from records of three accessible control-loop signals. This is an extension of work by J. Reswick and others. R. Kochenburger of the U. S. considered the problem of maximizing the probability that the error in the controlled variable is in a given band. From the spectral density of the disturbances on a water turbine, I. Obradovics and M. Mesarovic of Yugoslavia were able to obtain optimum adjustment of the turbine. Y. Sawaragi and S. Takahashi assumed a sine wave plus Gaussian input to a zero memory nonlinear device and secured equivalent gain for these inputs.

In other sessions Ya. S. Typsin of the U. S. S. R. showed how to obtain optimum performance for a sampling control in the case of stationary random disturbances. Papers by J. C. West of England, K. Klotter of the U. S., and Ch. Hayashi of Japan were concerned with frequency response

THE RESOLUTION

The Heidelberg meeting was the third international control conference. The first was held at Cranfield, England, in 1951, and the second, the Frequency Response Symposium, at New York City in 1953. All of these meetings were nationally sponsored, but open to participants from other countries. Because of the need for additional conferences of this kind, the following resolution was adopted at Heidelberg on Sept. 27:

"The undersigned favor the founding of an international federation of automatic control and declare themselves prepared to work in their respective countries for the organization of such a union. This federation is to have the following objectives:

1. **To facilitate the interchange of information in automatic control and to promote progress in this field.**
2. **To organize international congresses on automatic control."**

The resolution was signed by:

Otto Grebe, Germany
G. Ruppel, Germany
G. Müller, Germany
H. Kindler, Germany
W. Pohlenz, Germany
R. Oldenburger, U. S.
H. Chestnut, U. S.
A. Tustin, Great Britain
J. Coales, Great Britain
J. Westcott, Great Britain
A. Letov, U. S. S. R.
H. Märzendorfer, Austria
M. Mesarovic, Yugoslavia
J. Janssen, The Netherlands
J. Balchen, Norway
J. Jensen, Denmark
P. Nowacki, Poland
G. Evangelisti, Italy
J. Boas-Popper, Israel
M. Ajnbinder, Belgium
Ph. Passau, Belgium
V. Broïda, France
L. Hámos, Sweden
B. Hanus, CSR (Czech.)
S. Vladimir, CSR
K. Izawa, Japan
P. Profos, Switzerland

Send letters concerning the proposed federation to Dr. G. Ruppel, provisional secretary, at:

VDI/VDE Fachgruppe Regelungstechnik
Prinz-Georg Strasse 79
Dusseldorf 10, Germany

A carbon copy of the letter to Dr. Ruppel is to go to:

Prof. Rufus Oldenburger
Mechanical Engineering Dept.
Purdue University
Lafayette, Ind.

for nonlinear systems, nonlinear damping, and other phenomena.

Ed. note: Some of the papers described above are reviewed in this month's *Abstracts* section, page 166. Complete proceedings of the conference can be obtained by writing VDI/VDE Fachgruppe Regelungstechnik, Prinz Georg Strasse 77/79, Dusseldorf 10, Germany. The price is 75 marks ($18).

More Observations on Heidelberg

FROM LOWEN SHEARER, MIT

The Heidelberg papers were largely based on well-known concepts applied in various ways to hypothetical or real control problems. There was no evidence of any significant "break through" of the analytical barriers surrounding control technology today, and the available concepts and techniques were applied to more or less conventional types of systems.

Very little was said about how to characterize a system properly or about how the selection of process and component parameters in the design stages of a development program can be made to achieve "optimum automatic control". In other words, most of the authors took it for granted that a given process was to be controlled without tampering with anything inside the process, and then proceeded to show how to achieve "optimum control" of one kind or another for this given process. In most cases the processes which were controlled were linear dynamic systems having relatively simple characteristics. Although there was a great deal of interest in analog computers and computing machines in general, there seemed to be little realization yet of how to employ such tools most effectively. There was a lack of understanding of how to characterize a system in such a way that any or all of its basic parameters might be properly chosen to achieve desirable closed-loop control characteristics. Of outstanding importance in this connection was the lack of information about nonlinear effects in processes and control components. Very little was said, also, about the characteristics of nonlinear processes in terms of basic system parameters, or constants, of the limiting conditions under which linearized analysis can be properly applied, or of the steps that must often be taken to maintain proper surveillance of operating conditions (boundary conditions) of nonlinear systems under specific control conditions. (This criticism also applies to a somewhat lesser extent to many of the control conferences in the U.S.)

MORE EUROPEAN CONCLAVES

Antwerp Sept. 17–18

Writes J. M. L. Janssen (CtE, Nov. '55, p. 58) about the recent Conference on Automation organized by the Royal Flemish Institute of Engineers:

"Attendance at this conference was about 200. After its formal opening (see picture below) the meeting was addressed by the Belgian minister of communications, who drew attention to the progressive plans for further automation in the Belgian telephone system, railway system, and post office. He emphasized that small countries like Belgium should be very active in this field if they are to maintain an adequate standard of living.

"Most of the papers were of an educational character. Apart from an intriguing discussion by L. R. Mehl of Paris on an "electronic lawyer", no

OPENING SESSION IN ANTWERP
The Belgian Conference on Automation was opened by C. von Rooy, president of the Technological Institute of the Royal Flemish Institute of Engineers and vice-president of the Belgian Institute for Automatic Control & Automation. On his right was the first speaker: E. Anseele, Belgian minister of communications.

When it comes

startling novelties were put forward.

startling novelties were put forward. An interesting comment by Prof. R. Molle on the place of electronics in automatic control is, however, worth mentioning. He said that in the field of communications electronics was without a competitor. Electronic engineers, on the other hand, have found it difficult to realize that in the field of automatic control, where there are well established pneumatic and hydraulic techniques, the situation is quite different."

Stockholm, Sept. 17–21

Three full days of technical papers on subjects ranging from automatic process control through computers and nuclear instrumentation and into the new tools for on-stream chemical analysis made this Fourth International I&M (Instruments & Measurements) Conference one of the most important control conclaves held on the continent this year. There were nine contributions from the U.S. among the 72 papers, including a report on data gathering in engine test facilities by Mel Fusfeld (CtE, Aug. '56, p. 57), the use of nuclear magnetic resonance in chemical analysis by J. Shoolery of Varian Associates, and a lecture by T. V. Parke of Beckman Instruments on mass spectrometers. Turn to page 166 for abstracts from some of the sessions.

STOCKHOLM EXHIBITS

Ron Marshall (left) of Taylor-Short & Mason, Ltd., London, looks over a catalog with Torston Nordell of Kihlströms Manometerfabrik, Stockholm.

Servos, stem-thermometers, diodes, switches, indicators, etc.—all part of the German equipment distributed by Bo Palmblad AB.

From MOOG . . . a Dual Input Servo Valve for Flight Control

Pilot boost servos for control surface positioning are commonplace. These servos are usually necessitated by high control surface aerodynamic loads which make direct control through the pilot's stick impracticable. Generally, they are mechanical-hydraulic in nature.

Today, as aircraft operational requirements increase, it is necessary to add artificial flight stability augmentation through these servos. Also, aircraft autopilots must work through this medium. These modes of operation generally require electro-hydraulic servos.

To coordinate these functions, the Moog Valve Company introduced, and is now in full production on, its Dual Input Servo Valve. These units permit direct mechanical-hydraulic flight control, combined mechanical-hydraulic and electro-hydraulic control, and electro-hydraulic control alone. Full mechanical override for safety is always possible and self-contained solenoid and lock-out arrangements permit full flight mode selection.

Employing an entirely new principle of summation, the Moog units accomplish the electro-mechanical mixing function without linkage in a single, integrally-designed package. By elimination of linkage inertia and backlash, the Moog Dual Input Valve greatly increases low amplitude resolution and frequency response. It simplifies the entire control system and is far more compact than other dual input mechanisms.

The Dual Input Servo Valve was developed by Moog's creative engineering staff. This team approach is available to industry to produce advanced electro-hydraulic servo components.

MOOG VALVE CO., INC., PRONER AIRPORT, EAST AURORA, N.Y.

MOOG

WHAT'S NEW

All Around the Business Loop

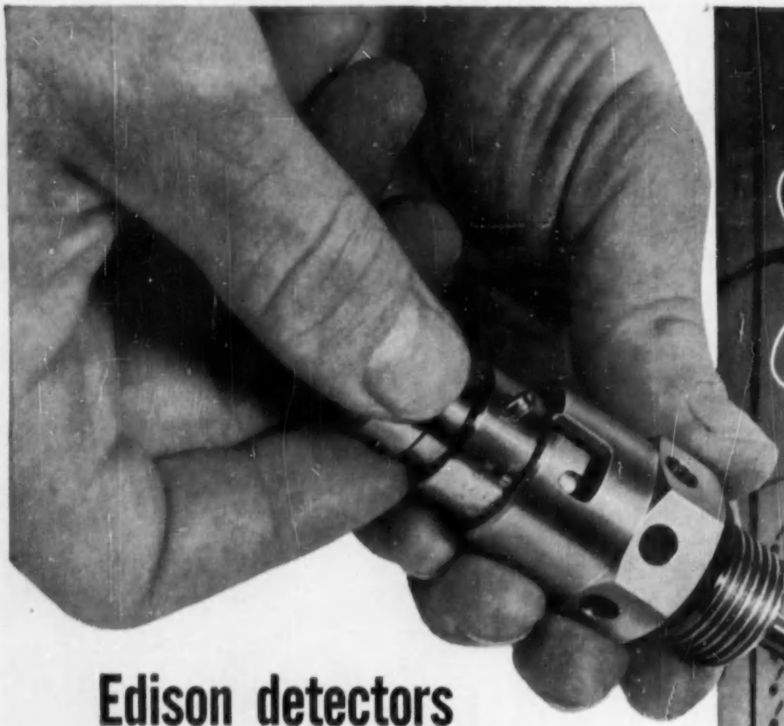
▶ Three of the nation's biggest manufacturers of data processors put their systems to work during the recent national election, and there was work enough for all. Still, it seemed that the heaviest burden was borne by **IBM's** 650's, simply because of the dignified restraint under which these machines had to operate. While **Remington Rand's** Univac and **Underwood's** new Elecom 125 matched diodes and vacuum tubes in a pre-return prediction tournament, the 650's had to be content with being strictly a high-speed messenger boy giving nothing but the facts.

Speaking of diodes, it is interesting to note that the largest order ever made for the germanium type was put through just weeks before the election, but never got into the contest. Calling for the order was **Logistics Research, Inc.**, and filling it was **Hughes Aircraft Co.** Sets of 6,000 will go into Logistics' Alwac computers, which, basking in a 168-per cent increase in sales, were kept busy enough with commitments from the U. S. National Security Agency, Weather Records Center, Institute of Gas Technology, U. S. and Canadian military establishments, and colleges and industries. Further diode purchases will be made, according to Vice-president A. Y. Baker, when the time comes to outfit the new Alwac 800, which takes 20,000 units.

IBM, which cooperated with NBC, agreed beforehand that no predicting would be done. Mutually, IBM, NBC, and the Associated Press decided upon a division of the country into 11 areas and in each one a collecting city was picked, based upon the available facilities. NBC purchased the necessary AP wires in each area and had them directed to the collecting city. IBM purchased the **AT&T** circuits.

Election returns from the AP wires were transcribed by NBC personnel onto IBM cards. Each card was key punched and key verified, then transmitted via IBM Data Transceivers to the collecting cities. Relay and check points for transmitting data were established at Los Angeles, Kansas City, Washington, and New York. At each point an IBM 650 made validity tests on transmitted returns. Checks made sure that: each return was greater than the one before; actual returns were not greater than state possibilities; votes increased in both parties, not just one,

(Continued on page 152)



Edison detectors give speedy warning of overheat in atomic pile

Self-monitor design assures fail safe operation

New Edison Resistance Temperature Detectors are especially developed to meet the exacting demands of the atomic power industry. These detectors are now helping forestall costly fuel cell damage by providing near-instantaneous detection of a rise in temperature in light water moderators.

Super reliable and simple in design, Edison detectors eliminate complex electronic components. Some are rated at 0.8 seconds maximum response time and the high temperature types give an accuracy of $\pm 1.0\%$ at 750°C. Radiation- and corrosion-resistant, Edison detectors have quick disconnect features for reduction of installation and maintenance time.

Write for Bulletins 3016 and 3036 for information on types of Resistance Temperature Detectors and remote temperature monitoring systems for every purpose.

Thomas A. Edison

A GREAT NAME CONTINUES GREAT NEW ACHIEVEMENTS

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INSTRUMENT DIVISION • 38 LAKESIDE AVENUE • WEST ORANGE, NEW JERSEY

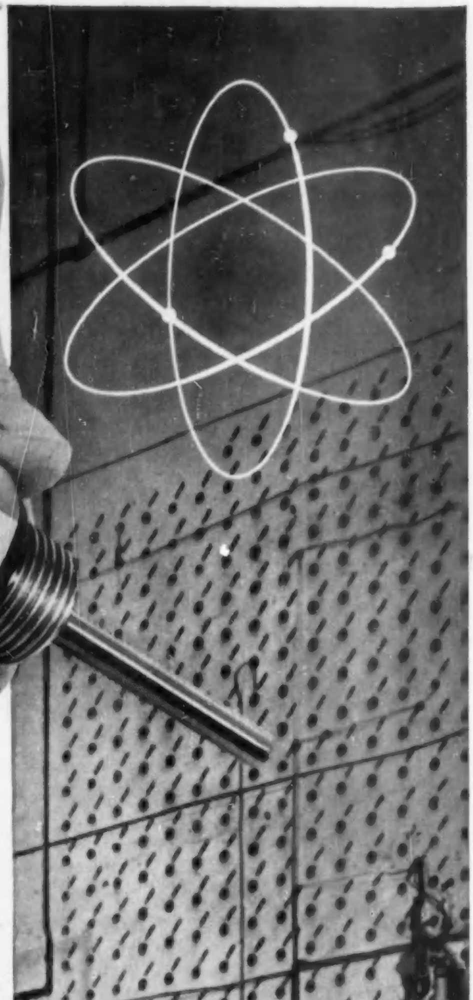
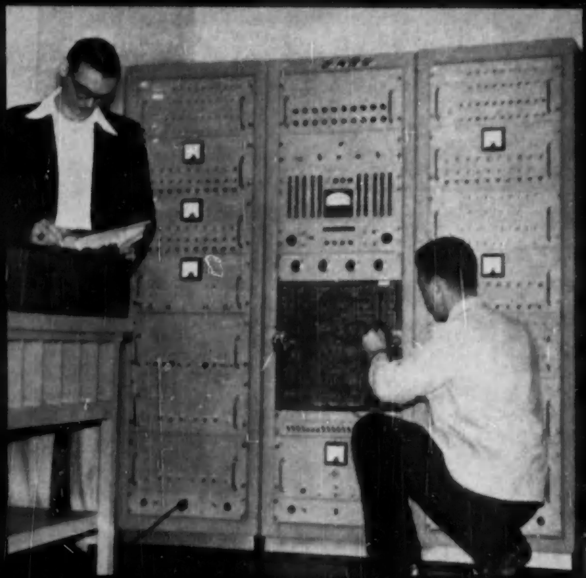


Photo courtesy of Union Carbide & Carbon Corporation



GEORGIA TECH ADDS AN ANALOG COMPUTER FACILITY

■ Convincing evidence that analog equipment not only broadens the scope but also increases the efficiency of a digital computer facility is again corroborated by Georgia Tech.

Engineers of the South's leading engineering and industrial research activity, the Georgia Tech Engineering Experiment Station, found an early need for analog equipment to supplement their extensive digital computer facilities (the Rich Electronic Computer Center) in the solution of physical problems. Analog techniques for real-time solution of problems involving continuous quantities are typically ten to one hundred times faster than digital. When digital machines are required for high-accuracy resolution of such problems, analog equipment can quickly spot critical areas to be given detailed examination.

Georgia Tech's Analog Computer Laboratory had another reason for existence — the training of graduate students in computing theory and technology, an area in which **analog** concepts are a **must**.

EASE* equipment, chosen for this key assignment, offers such features as simplicity of set-up and operation, high accuracy, and freedom for expansion or modification to meet future requirements.

These EASE* features can give you a years-ahead start in solving analog computer problems, in personnel training, or in supplementing digital computer operation for utmost utility. Why not write **now** for details — please address Dept. L12

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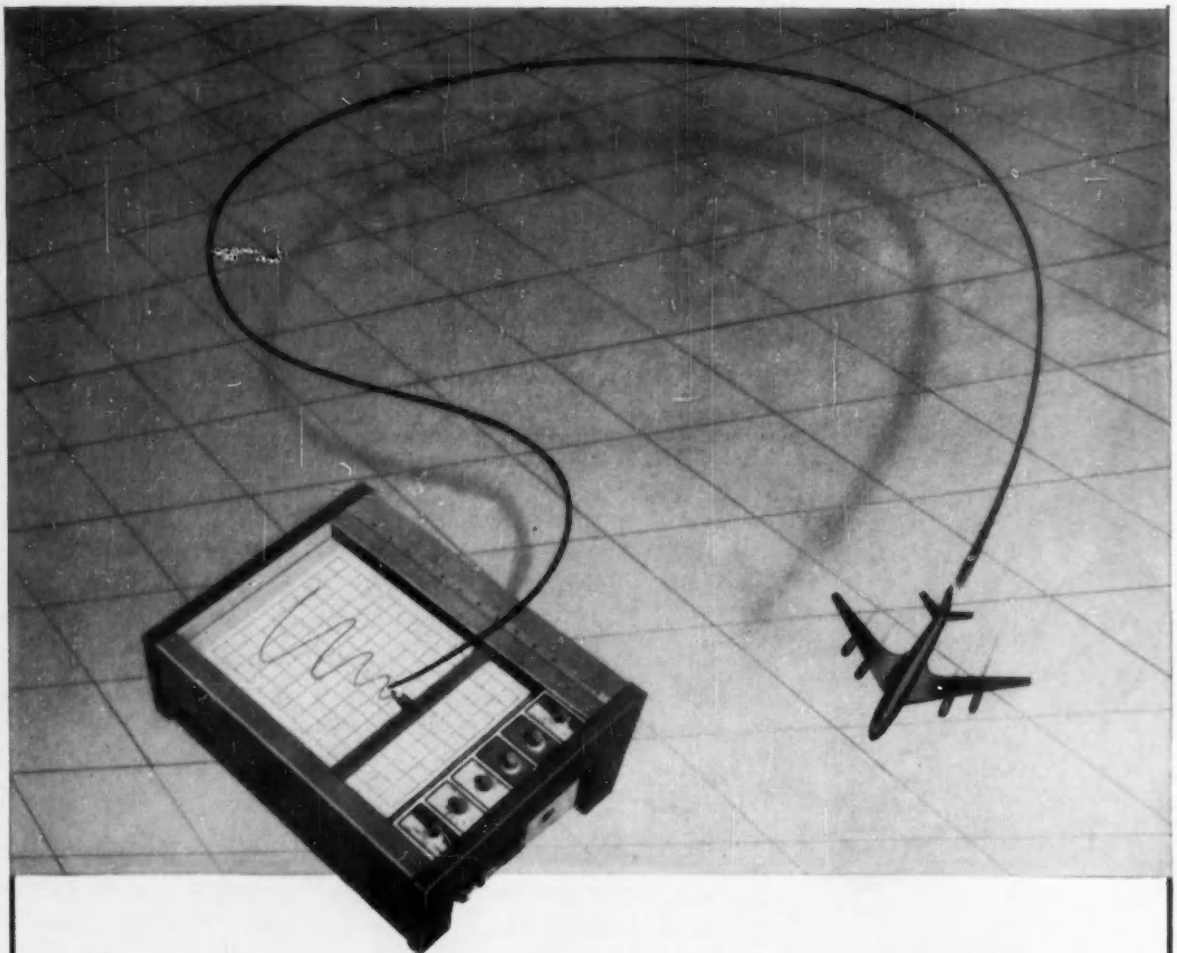
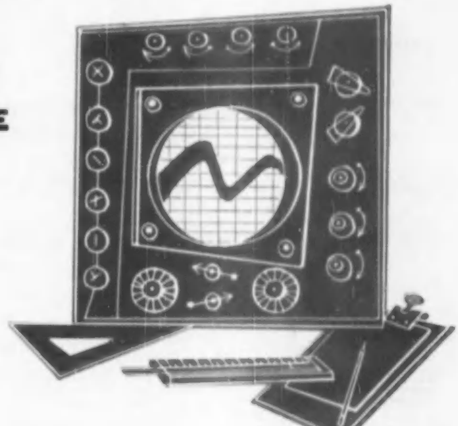




How Control Makers Will Train Your Technicians

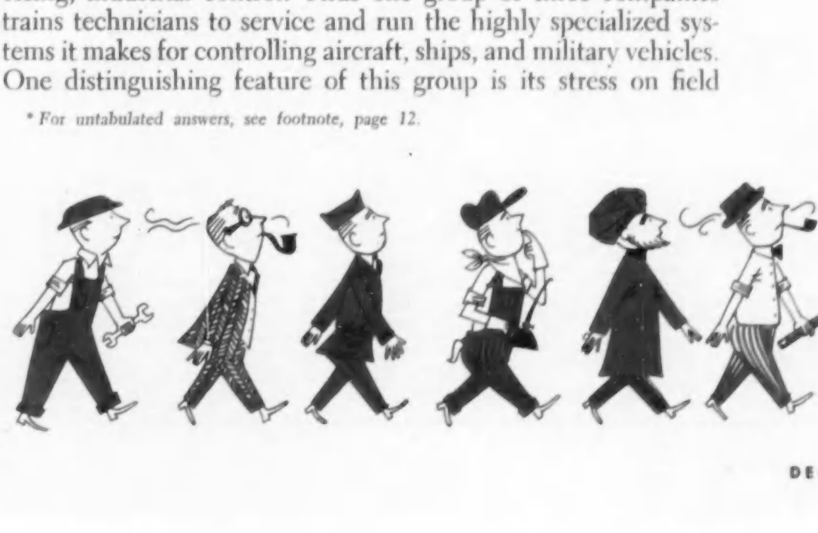
A recent study by McGraw-Hill's Department of Economics indicates that the users of control will purchase over $4 billion worth of equipment in 1957. The incoming devices and systems will bolster an already incredible array of complex, highly specialized measurement and control equipment now being used throughout business, the military, and industry. But to the users they will create this pressing question: where will the trained technicians come from to install, maintain, and operate the new systems?

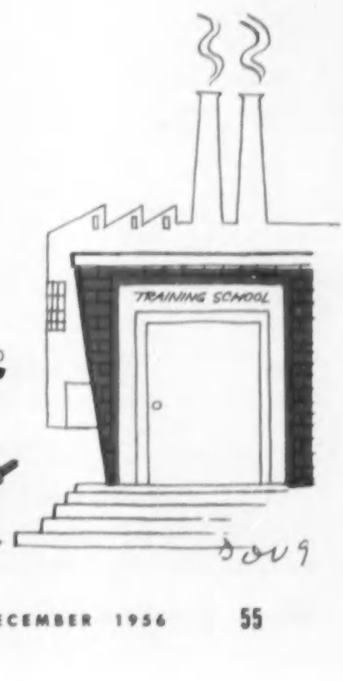
Who'll run 'em after you buy 'em?

One powerful answer to this question resides in the training schools—formal and informal—offered to control users by the makers themselves. Most of the 2,000 odd companies that manufacture specialized products for the control field are prepared to back up their equipment either with informal in-plant or use-site instruction, or through organized training facilities. It is the growing emphasis on this latter category—the formal, organized customer training school—that prompted CONTROL ENGINEERING recently to survey 100 control manufacturers. By Oct. 15, 33 companies returned complete answers on their organized facilities. The answers are crammed into the next two pages.*

To help the user with specific requirements, the table groups control-maker schools into four categories: aircraft and ordnance; analysis and test instruments; computers and data processing; industrial control. Thus one group of three companies trains technicians to service and run the highly specialized systems it makes for controlling aircraft, ships, and military vehicles. One distinguishing feature of this group is its stress on field

* *For untabulated answers, see footnote, page 12.*





GROUPS: I—AIRCRAFT AND ORDNANCE
II—ANALYSIS AND TEST
III—COMPUTERS AND DATA PROCESSING
IV—INDUSTRIAL CONTROL

SOME OF THE SCHOOLS ORGANIZED

COMPANY	SCHOOL FACILITIES			
	STAFF	TEXTS	EQUIPMENT	FIELD TRIPS
I. LEARCAL DIV., LEAR INC. Santa Monica, Calif.	3 electrical engineering graduates	prepared by school staff	test & special eqpt. to service autopilots	actual in-flight demonstrations
KOLLSMAN INSTRUMENT CORP. Elmhurst, N. Y.	3 eng. grads with minors in teaching	manuals & texts prepared by Kollsman	actual system or eqpt. under instruction	in field—also company facilities
SPERRY GYROSCOPE DIV. Great Neck, N. Y.	26 . . . some PhD's. in math, engineers, technicians	student training notes and technical reports	product for study & associated test eqpt.	flight is made in certain programs
II. BAIRD ASSOC.-ATOMIC INSTRUMENT CO. Cambridge, Mass.	5 with science and engineering degrees	outlines compiled by engineering staff	direct reading spectrometer & spectromet	no
BAUSCH & LOMB OPTICAL CO. Rochester, N. Y.	10-13 graduates optically trained	manual on each instrument	instruments & assoc. test and repair eqpt.	glass plant; lens grinding; assembly
BRUSH ELECTRONICS CO. Cleveland, Ohio	2 engineering & sales personnel	brochures, service notes, catalog sheets, etc.	misc. specialized test equipment on bench	no
CONSOLIDATED ELECTRODYNAMICS CORP. Pasadena, Calif.	2 full-time plus eng. & service guest staff	prepared by technical services department	instruments plus "breadboard" circuits	no
NORTH AMERICAN PHILLIPS CO. Mount Vernon, N. Y.	12 including university professors	book on X-ray diffraction designed for course	complete X-ray diffraction eqpt. on benches	no
III. ELECTRODATA DIV., BURROUGHS CORP. Pasadena, Calif.	30 grads in EE, math, physics; ex-teachers	various company-designed specialized handbooks	3 complete DATATRON systems plus test eqpt.	customer systems are visited and studied
ELECTRONIC ASSOCIATES, INC. Long Branch, N. J.	4 with backgrounds in EE and physics	original texts on test & operational procedures	test racks & standard electronics test eqpt.	tour of facilities & computation center
IBM CORPORATION New York City	200 with college degrees and IBM training	machine operation manuals & diagrams	IBM equipment	no
LOGISTICS RESEARCH, INC. Redondo Beach, Calif.	10 graduate engineers, mathematicians	theory & practice step-by-step guide book	on-job production, testing, maintenance	field service installations & maint.
J. B. REA CO. Santa Monica, Calif.	2 with math background and about 5 yrs exper.	none	READIX computer in service facility	no
REEVES INSTRUMENT CORP. New York City	full-time educator plus assigned engineers	technical handbook, data sheets, test data	all normal lab eqpt. for on-job training	trips to test dept. and production line
REMINGTON-RAND DIV. New York City	25 grads with systems & programming training	various manuals—depends on specific course	see field trips	field installations provide "bench work"
UNDERWOOD CORP. Long Island City, N. Y.	6 people from programming dept., plus analysts	Elecom 125 system manual	no	
IV. ASKANIA REGULATOR CO. Chicago, Ill.	service department personnel	company bulletins	stock regulators for assembly and test	no
BAILEY METER CO. Cleveland, Ohio	3 full-time graduate engineers	special manuals	tool, air, gage equipped benches	no
THE BRISTOL CO. Waterbury, Conn.	11 guest-lecturing-practicing engineers	data sheets, manuals, and textbook reference	complete bench facilities for test, service	nearby installations are visited
FISCHER & PORTER CO. Hatboro, Pa.	5 service engineers & dept. supervisors	F&P catalogs and instruction bulletins	rigs for checking & calibrating equipment	no
THE FOXBORO CO. Foxboro, Mass.	4 eng. (field, design, etc.), 1 instructor	special texts prepared by Foxboro personnel	complete bench setups for 26 students	no
GENERAL ELECTRIC CO. West Lynn, Mass.	2 service engineers, design eng. if needed	factory instruction & tech. training plans	bench repair plus std. test instruments	visits to GE factories to see methods
THE HAYS CORP. Michigan City, Ind.	10 primarily service, plant eng. guests	Hays instruction manuals & supplements	operational & cutaway eqpt. models	3-4 hr trip through local central station
INDUSTRIAL NUCLEONICS CORP. Columbus, Ohio	8 graduate eng. from all departments	manuals plus appl. eng. drawings of systems	working system units plus demonstrations	visits to factory installations
LEEDS & NORTHRUP CO. Philadelphia, Pa.	2 college grads. with test, prod. background	manuals plus specially compiled material	panels, units, test eqpt., shop tools	no
MANNING, MAXWELL & MOORE, INC. Stratford, Conn.	10 graduate engineers with field experience	instruction manuals & sales bulletins	calibration & trouble-shooting equipment	no
MINNEAPOLIS-HONEYWELL REG. CO. Philadelphia, Pa.	7 & supervisor . . . all with field experience	co. manuals plus special staff bulletins	entire floor of benches, test eqpt., panels, etc.	no
POWERS REGULATOR CO. Skokie, Ill.	4 graduate engineers—part-time	ISA and ASHVE recognized texts	portable tables	no
RELIANCE ELECTRIC & ENGINEERING CO. Cleveland, Ohio	full-time engineers plus guest lecturers	operating instructions, eng. manuals, schematics	electronic panels connected to motors, etc.	no
THE SWARTWOUT CO. Cleveland, Ohio	3 people from service department	2-vol. book of instruction, well-illustrated	calib., trouble-shooting, using instr. components	no
TALLER & COOPER, INC. Brooklyn, N. Y.	3 engineers & tech. men experienced in eqpt.	complete texts on parts, assbly, maintenance	facilities to repair & adjust machines	visits to installations nearby
TAYLOR INSTRUMENT COMPANIES Rochester, N. Y.	19 application engineers—2 full-time	instruction books, tech. papers, FR text	lab space for 32 men with 2 men per bench	factory tour
WESTINGHOUSE ELECTRIC CORP. Pittsburgh, Pa.	4 control engineers	CYPAK manual	individual CYPAK assemblies	no

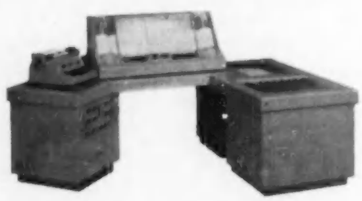
BY CONTROL MANUFACTURERS

THE COURSES			THE STUDENTS				ENROLLMENT	
TYPES	LENGTH	EXAMS	NO. IN COURSE	NO. PER YEAR	WHERE FROM	PREREQUISITES	METHOD	ANY WAIT?
one type only	1 week	final	5	250	from military & distributor service facilities	none	written application from his employer	no
modify to fit student backgrounds	3-7 wks	as needed	18	200	military, airframe mfrs., airlines, systems mfrs.	determined by the customer who sends him	contractual or other agreement	2 months
operation; maintenance; overhaul	3 days to 9 months	yes—varies with course	10	to 1,000	aircraft, govt., shipping, executive aircraft, cargo	depends on course—basic knowledge essential	customers request training on specific products	3 months at most
spectrometer; spectrophotometer	5 days	no	40-60	100	metals industry, industrial & research labs	users only are invited to attend course	write well in advance of Oct. 22 deadline	only one course a year
complete B&L line review	5 days	no	4-8	50	labs, surgical schools, instrument dealers	selected by management of respective companies	invitation from B&L Optical Co.	only 6 courses a year
Brush "line" course; short refresher	5 days	no	10	60	manufacturing, research, and development	fundamentals of electr. and mech. measurement	direct application to Brush or factory rep.	5 weeks
operation; maintenance; theory for supervisors	few hrs to 5 weeks	daily & wkly	12	200	from customer plants—aircraft to refining	good electronics background very helpful	through field sales offices after purchase	up to 3 months
basic theory to present-day practices	1 week	no	150	500	all types of industry	none	merely write that you wish to attend	no
management; coding; programming; maintenance	maint. — 5 mos others — 3 wks	weekly	30	750	industry, services, research, etc.	an EE degree with pulse expr. for maint. course	write field office or direct to Pasadena	1-3 wks
maintenance; operation and problem setup	4 days	no	15	150	research & development groups, industry, govt.	analog computer experience	invitation	no
key punch & machine operators; wiring; systems	2 days to 4 weeks	weekly	15	70,000	all types of locations, classes go to them	aptitude tests and prerequisite machine exams	through local office & local sales reps.	1 month
programming; maintenance; production techniques	prog. — 2 wks serv. — 2 mos	weekly	10	250	mfg., process, govt., business, transport.	grad. eng. or mathematics, or aptitude	write or call and make arrangements	2 weeks
depends on background of students	1-2 wks	no	10	200	engineering, aircraft, chemical, etc.	none	through correspondence with J. B. Rea Co.	variable
level of maintenance course varies to group	2 wks to 3 months	no	10	120	across all business & industry, institutions	basic knoweldge or electronics	by customer or government request	few wks
intro.; programming; advanced pr.; logic	2-8 wks	bi-weekly	15	1,500	from industry, business, government	none—except for advanced programming	through local RR branch or RR training director	2 months
programming; logic-maintenance	2-4 wks	no	20	100	industrial, casualty firms, govt., etc.	none	contact training director of the division	no
combustion controls; edgeguide controls	2 days	no	8	100	steel mills, process plants in industry	must be customers	send in name of man who will attend	usually
only one course	2 weeks	final	20	250	mainly power co.'s, but some process plants	none	request by letter, wire, or 'phone	5-6 mos
varied to meet needs of students	1-3 wks	no	8-10	70	mainly process, but all areas of industry	recommendation by student's company	write giving man's name & primary interest	not often
only one course	1 week	no	10-12	40	all types—no restriction	none	request on company letterhead	no
general course; special DYNALOG	3 weeks	no	20	250	process industries all over world	at least 6 mo exper. plus h.s. physics, math	application from customer mgmt.	3 months
depends on student backgrounds	1-5 days	no	15	150	chemical & metal-working industries	no—but technical background recommended	write to Mr. Shattuck, Product Service, GE	no
basically service only	5 days	one	25-30	25-30	wherever combustion control is located	must be responsible for Hays eqpt.	direct request	no
oriented to special industry groups	1 week	simple exercises	12	100	nationwide industrial firms	should be associated with an installation	letter to Sales Training Dept.	yes
separate courses to suit industry groups	2 weeks	no	20	700	process, utilities, labs, govt., & education	nomination by L&N customer or real interest	Apply to Philadelphia L&N office	maybe
technical & plant; mgt. & sales	1 week	no	20	60	usually from process—all welcome	users or contractors of MM&M equipment	indicate desire to attend course	only 3 a year
depends on product coverage required	2, 3, 5, 14 weeks	at end of each subject	20	350	all inclusive	none	written request	3-5 mos
varied to suit students	2 weeks	final	4	40	various customers	none	request through local sales office	no
varied to suit industry requirements	1 week	daily	12	300	process, ferrous & non-ferrous, machine tool	Reliance customer with electrical background	request through district office	6 months
maintenance; engineering course	5 days	no	25	100	primarily refining & chemical—many others	none	reserve through local sales office	sometimes
according to application	1-3 wks	no	7	30	bridge & road authorities, airfields	must be sent by company	automatic if a customer	no
basic; process control; dairy; freq. response	basic — 2 wks others — 1 wk	basic course only	32	275	process industries	try to fit course to background	contact local sales representative	3 months
one course	1 week	no	33	100	industrial cross-section	none	through local salesman	yes

ADSMANSHIP HANDBOOK

Chapter V; Volume I THE RECRUITMENT AD THAT WANTED TO BE A COMIC STRIP

CHALLENGING OPPORTUNITIES IN THE FIELD OF TOMORROW



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training: all three companies take their students out or even up in the air to work on operating systems.

The five makers of analysis and test equipment that answered the survey use their brief courses (mainly one week) to focus on theory and function rather than field application. This approach, they believe, will enable the user to broaden his own ability to put the new tools of product measurement and system test to work in the many unplumbed applications in his plant.

An EE for maintenance?

Operational techniques are emphasized in the courses offered by the five digital manufacturers responding to the survey. All recognize the need to equip technicians to program and code (and simply operate) the rather complex digital systems they now have on the market. Because of the complexity of these systems, background is especially important: most firms require a knowledge of electronics and/or computer experience. One even suggests that the trainee be a graduate engineer with pulse experience if he is to take the maintenance course.

A much broader approach to the service and operation of automatic control systems is offered by the 17 industrial control firms in the survey, whose courses run from two days to 14 weeks. Many in this group have been conducting user schools for as long as 20 years, and several have developed special courses to suit the industrial background of the trainee.

8,000 trainees plus IBM

Over all, the most impressive thing about the survey is the astounding number of people that these few manufacturers train. Excluding IBM (with its fantastic "mobile" program which handles 70,000) roughly 8,000 technicians pass through the portals of 33 control-maker training schools each year. What would the grand total be if all programs and all firms were included in the survey?

The tabulation reveals some interesting uniformity in the scope of user training by control makers:

▶ all courses (with the exception of Koilsman's, some of Consolidatd Electrodynamics', and the Westinghouse "CYPAK" class) are tuition free

▶ most firms are staffing their schools with graduate engineers, many of whom are trained to teach

▶ most of the companies require that their "students" be customers (at least 12, however, do not)

One more thing is quite apparent from the table: more than half of all these control-maker schools seems to be enrolled to capacity long before classes start. So if you plan to send a man—get in your request right now.

testing components with Burroughs pulse control systems

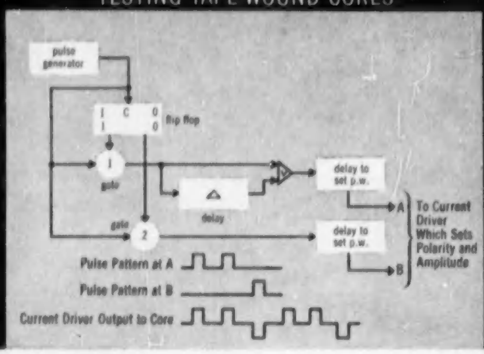
modern methods for testing cores

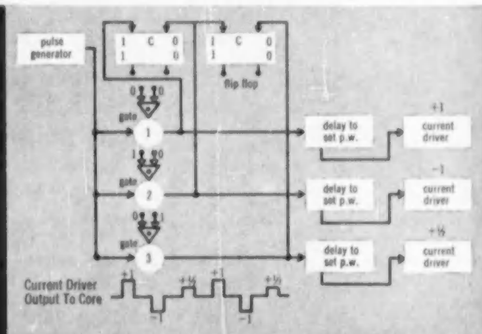
The future of magnetic cores in information handling systems is already well assured. Their high reliability, fast action, small size, and low power consumption stimulate the imagination of more and more engineers working in data processing, weapons systems, and control. And every day finds these new components included in more new designs.

One problem still facing those who want to exploit these exciting properties is the lack of precise uniformity in cores made on a production basis. For as Burroughs has found through 5 years of working with the pioneers in core applications, uncertainties still exist. And before cores become standardized, many changes will probably be made. Those who want to take advantage of the great potential in this new component now must use reliable test procedures which precisely check the tolerances of each core, and are versatile enough to check for the new core specifications of tomorrow.

Burroughs Pulse Control Systems answer this need for leading manufacturers and users of cores by simulating the actual conditions under which each core produced will eventually operate. When conditions require a change in core operating characteristics, the testing system is changed at will, in a matter of minutes, to meet the new requirements.

TESTING TAPE-WOUND CORES





TESTING FERRITE CORES

Shown here are typical examples of how these core manufacturers, including Burroughs own core production department, use Burroughs Pulse Control Systems to check tape wound and ferrite cores. An interesting booklet describing core testing in greater detail is yours for the asking. But if you want to test another component by digital techniques, just send us your problem. We'll be glad to work it out, at no cost, and show you how Burroughs Pulse Control Systems can save you hours of engineering time and production headaches.

BURROUGHS

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Control ENGINEERING

DECEMBER 1956

Our Control Personality this month (page 15), Dr. Robert J. Jeffries, offers this guest editorial on the elements of a program for training people in our field.

Program for Training

In today's ideological conflict between East and West, the survival of our concepts of individual dignity and opportunity depends chiefly on our continuing prosperity and on the example we set. This requires, among other things, more and better-trained engineers to conceive and design more machines incorporating the latest products of control technology, and a supply of highly skilled technicians to operate and maintain this equipment. It requires also that we continually upgrade existing personnel to enable them to keep pace with the growth of the field.

Several things can be done to meet the challenge. Drawing on our knowledge and associations, we might address ourselves to the following:

- **Bolster science education in secondary schools – this requires better teachers.**
- **Enhance the scope and effectiveness of collegiate programs – this requires industrial and community support.**
- **Attract people to careers in the control field – this requires broader public appreciation of its content and potential.**
- **Cultivate a better understanding of our technology at all levels of management and employment – this requires an effective and varied industry educational program.**
- **Translate the sophisticated theories of academic and military programs into economically justified equipment and techniques for industry – this requires an effective two-way communication in needs, interests, practices, and experiences.**
- **Develop a practical way to tap the great reservoir of experience already in the literature – this requires an effective technique for storing and retrieving that makes the information available to all.**

How can we implement such a program? A good start has been made by the Instrument Society of America with its recently established Foundation for Instrumentation, Education & Research (see *What's New*, page 19). The Foundation's functions will be largely conceptional and catalytic. In general it will assist in developing education and research projects in instrumentation not only for other societies, but for governmental, industrial, and educational groups at all levels. These projects will be nurtured by the ISA, by individual industries and industrial trade associations, by civic, labor, and fraternal organizations, and by educational institutions and government agencies.

The success of the Foundation's program – of any program for training, for that matter – depends on how much support it gets from that group certain to benefit the most from it – the men in the field.

ROBERT J. JEFFRIES

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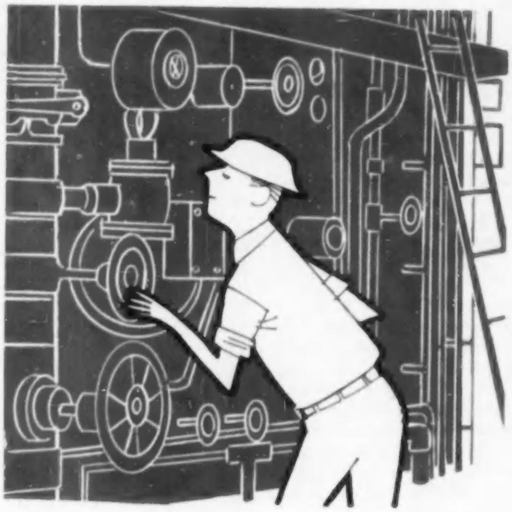
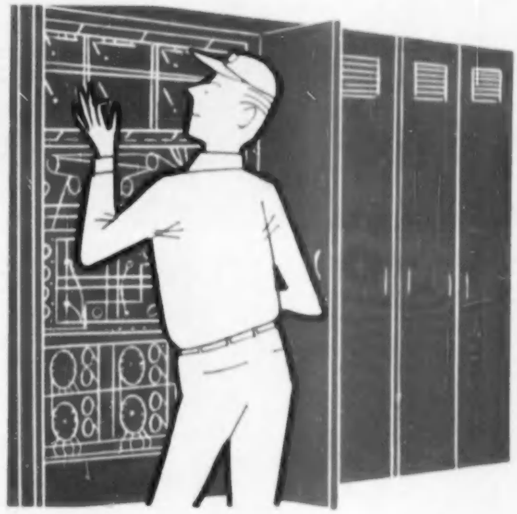
(■) Indicates factory-level service available.





How Two Companies Meet Their Needs for Control Technicians

THE GIST: In a manufacturing or processing business, control reliability, achieved through prompt and competent instrument maintenance, results in increased efficiency and production. Without effective maintenance, failure of even a single instrument or component can result in excessive losses. One way to obtain this effective maintenance is to establish a comprehensive training program. Such a program requires time and money, but the benefits realized far outweigh the expense.

The company benefits through the reduction of future maintenance costs and improved current production, the technician benefits through increased morale—he becomes an important asset to the company, sees opportunities for recognition, advancement, and financial reward.

Recognizing that it might be more expensive not to train instrument technicians, many companies have made maintenance training programs a major function of their instrument departments. In this article two companies—Carbide & Carbon Chemical Co. and Ford Motor Co.—tell CONTROL ENGINEERING readers about their successful training programs.

HARRY R. KARP, Control Engineering,
with Harry Homewood, McGraw-Hill, Detroit,
John J. Dwyer Jr., McGraw-Hill, New York

Engineers, chemists, physicists, and metallurgists strive to improve existing manufacturing processes and develop new processes for one reason: increased productive yields. Achievement of this goal depends to a great extent on the complex instrumentation which keeps the plant under good control and running efficiently day in and day out for years. Thus a great deal of responsibility for keeping up production falls to the company's instrument department, and more particularly, to this department's instrument maintenance group.

Not only must this group perform routine functions, such as overhauling, calibrating, and servicing, but it must also be prepared to handle emergencies and to modify existing instruments and install new types demanded by plant and process improvements. This is why training programs for instrument technicians have become such an integral part of company operations. These programs, varying from company to company, illustrate by their very difference what each company wants in the way of trained technicians. That is why a full-scale survey of the programs would simply obscure many important features of good training. And why CONTROL ENGINEERING has decided to limit this article to two highly-successful training programs, one representing the wet process industry, the other manufacturing.

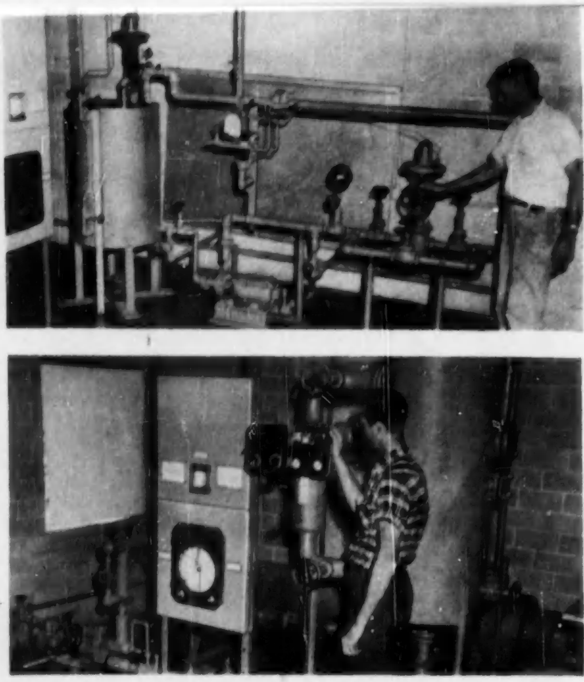


FIG. 1. "In our training laboratory," reports Carbide's Liford, "we have two independent processes. The first process (top) is an open tank with a Model 40 Foxboro level controller and a motor valve in the water outlet of the tank. We have a circulating pump, an orifice run, and a Foxboro d/p cell transmitting to a Taylor control station with a Foxboro Model 58 controlling a motor valve in the circulating line.

"The second system is a closed process (bottom). We have a pressurized tank and a Taylor pressure controller controlling the pressure by two valves. A Taylor temperature transmitter in the circulating line transmits to a Taylor control station and through a Foxboro Model 58 controls the valve in the stream of a heat exchanger. The tank liquid level is controlled by a Fisher Float type controller actuating a valve in the drain line from the tank.

"The operators use these instruments and processes to familiarize themselves with process control. The instrument man uses the instruments in conjunction with his Procedures Training and also operates the process to gain knowledge and experience on the control problems. I can simulate control problems and he can correct them or learn to diagnose them by operating the unit."

HOW CARBIDE TRAINS ITS INSTRUMENT MAINTENANCE MEN

E. I. Thomas, chief instrument engineer at Carbide & Carbon Chemical Co. in South Charleston, W. Va., cites the training program established at Carbide's new Seadrift, Tex. plant by instrument engineers Jack Walthall and Hubert Liford. These key men, transferred from South Charleston, were faced with the problem of selecting trainees with little or no experience in instrumentation or electronics and converting them into accomplished instrument maintenance technicians. Their first step was to bring in a trained industrial teacher to help prepare personnel selection procedures, training aids, study guides, and training manuals.

Pick the right people . . .

Because this is a new installation the men selected for the instrument training course are brand-new employees. All, then, are first screened to see they meet Carbide's usual employment requirements. Next, however, come evaluations to determine whether they can learn fast, absorb new information, and become technically proficient.

To ascertain these qualities, Carbide uses three widely-known tests. These tests, previously used at Carbide's Texas City plant, showed excellent correlation between prediction of a man's success as a trainee and his actual success after the training period. These tests are:

- Mechanical Comprehension Test, by Dr. George K. Bennett
- General Intelligence Test, by E. F. Wonderlic
- Industrial Training Classification Tests, by C. H. Lawshe and A. C. Moutoux

The personnel department is always on the lookout for men with previous electronic experience, and these are then interviewed by the instrument department managers. In discussing this practice at Carbide's recent interplant conference on instrumentation, Liford said: "I can foresee in the future great strides in electrical instrumentation, and it has been our experience that it is harder to teach a person electronics than it is pneumatics and mechanical instruments. If he has that background, he can apply that knowledge in very many ways to pneumatic and mechanical instruments, and we feel that if we can get a person with electrical training almost half of our training is accomplished right there."

Train them thoroughly . . .

The complete instrument maintenance training course covers about three and a half years. However, the exact length of time varies from trainee to trainee. Rather than force each man to progress at the same rate, Carbide adjusts the course to individual needs so that people who need more time to learn may have it. At the present time 17 students are being put through at Seadrift. No one has failed, no one has dropped out voluntarily, and all have received advancement. A similar program, with eight students, at Carbide's Torrance, Calif. plant, is proceeding with the same success.

Seadrift's training program consists of three phases, each of which gives the student three and a half hours of class and laboratory work per week, on company time. The more the men learn about instrumentation through their schooling, the more they apply on the job, where they work with more experienced maintenance men. And as their ability increases, so does their responsibility.

The first phase of the Seadrift training program makes use of company-prepared text—*Instrument Mechanics Base Training Manual.* This manual,

illustrated and simply-worded, introduces the trainee to his job and his responsibilities. Seven parts cover these subjects:

- ► THE JOB—duties, emergencies, housekeeping and safety
- ► THE PLANT-EQUIPMENT—valves, steam traps, pumps, compressors, turbines, electric motors, packing, equipment safety devices, columns, heat exchangers, and separators.
- ► THE PLANT-MATERIALS—air, gas, water, steam, electricity, caustic and lubricating oil.
- ► THE SCIENCE—basic physics and underlying fundamentals of temperature, pressure, etc.
- ► THE PLANT-PROCESSES—fluid flow and heat transfer, and their applications in distillation, absorption, stripping, drying, cracking, and steam generation.
- ► FUNDAMENTALS OF MEASUREMENT—temperature, pressure, flow, etc.
- ► FUNDAMENTALS OF INSTRUMENTATION—recorders, charts, ink, pens and pen arms, print wheels, and motor valve construction.

The Basic Training Manual familiarizes the trainee with his overall responsibilities, shows him how his section relates to other departments and groups, and creates an attitude of teamwork. In short, it integrates him into company operations.

Upon successful completion of the first step in his training (as determined by inventory tests given before starting and after completion) the trainee enters the second step, learning detailed procedures. Here another manual is used—*Instrument Maintenance Detailed Procedures Manual*—which is a combination of pertinent manufacturers' literature and company-prepared detailed procedure sheets.

The detailed procedure sheets apply to all instruments of that particular classification used in the plant. Procedures cover servicing, overhauling, troubleshooting, and range changing. In addition, the sheets refer to the applicable manufacturers' bulletins included in the manual.

A typical procedure sheet for a differential pressure indicator goes into such detail as:

check bearing and pivots
  clean and straighten
check linkage and bearing
  free if binding, or replace if sloppy
check zero
  close both lead valves
  open by-pass valve
  turn zero-adjustment screw until pointer is on zero
  open one lead valve
  close by-pass
  open other lead valve

Manufacturers' bulletins included in the manual reflect the plant's extensive instrumentation, which the men are trained to maintain. In this way the trainees receive benefits from their education, and the company from rapid and reliable maintenance of

TABLE 1—INSTRUMENT MANUFACTURERS' BULLETINS ADAPTED FOR TRAINING AT CARBIDE

PRESSURE
- Bailey Meter Co. Multi-pointer Gauge Section M-42-1
- Foxboro Co. Pressure Recorder Catalog #6-10
- Foxboro Calibration of Link Type Instrument Section 1-510

DIFFERENTIAL PRESSURE
- Bailey Fluid Meters for Steam Liquid Gauges
- Barton Instrument Corp. Flow Meters Bulletin 11C4
- Foxboro Instrument Diagrams with Explanatory Notes
- Foxboro Flow Meters Bulletin 460-1

TEMPERATURE
- Taylor Instrument Cos. Dial Thermometer Bulletin 98214

CONTROLLERS
- Bailey Mini Line Equipment B. G. 040-2
- Foxboro On-Off Controller Section 11-215
- Foxboro Model 40 Controllers Bulletin 461-2
- Foxboro Controllers Section 11-452 Model 40 Stabilog, Putting into Operation
- Fisher Governor Co. Level-trols Bulletin F-3
- Mason-Neilan Liquid Level Controller Series 12,000

TRANSMITTERS
- Foxboro d/p Cell Bulletin 420-1
- Foxboro Pneumatic Transmission Bulletin 415
- Moore Products Co. H/P Differential Pressure Transmitter Bulletin 1101
- Taylor Transaire Control System Bulletin 98097

RECEIVERS
- Bailey Instruction Section P11-2 For Operation and Maintenance
- Foxboro Model 52 Consotrol Controller-Calibration of Pneumatic Receivers
- Taylor Transet Recorders Bulletin 92106

MOTOR VALVES
- Fisher Diaphragm Motor Valves Bulletin FG-40
- Foxboro Pneumatic Control Valve Bulletin 277-2

VALVE POSITIONERS
- Bailey Positioner Section P99-31
- Foxboro Vernier Valvactor Type B Section 12-336

POTENTIOMETERS AND BRIDGES
- Foxboro Dynalog Sections 16-300 and 16-350
- Brown Inst., Minneapolis-Honeywell Reg. Co. Instructions Section 1467
- Leeds & Northrup Co. New Horizons with Speedomax ND-46-1954

TABLE 2—BOOKS FOR YOUR TRAINING COURSE

Detailed company-prepared texts and manufacturers' bulletins which make up most of the material for instrument maintenance training courses, often are supplemented by general books on instrumentation and related subjects. The following, used in the three-year training course of another instrument user, show the range of subjects taught here and serve as a guide in selecting training material for comprehensive instruction. Trainees receive these books in the order stated below as they advance in the program.

1. PRACTICAL MATHEMATICS, PART I: Arithmetic with Applications, Palmer Bibb, McGraw-Hill Book Co., Inc., New York.
2. VITALIZED PHYSICS (A Rapid Review of Physics), Carlton, College Entrance Book Co., New York.
3. FUNDAMENTALS OF PRESSURE AND TEMPERATURE INSTRUMENTS, Delmar Publishers, Albany, N. Y.
4. INSTRUMENTS AND PROCESS CONTROL, Delmar Publishers, Albany, N. Y.
5. BASIC ELECTRICITY, VOL. I, Van Valkenburgh, Nooger, and Neville, John F. Rider Publisher, Inc., New York.
6. BASIC ELECTRONICS, VOL. I, Van Valkenburgh, Nooger, and Neville, John F. Rider Publisher, Inc., New York.

the instruments and assurance of full production. The bulletins encompass these subjects:

- pressure
- differential pressure
- temperature
- controllers
- transmitters
- receivers
- motor valves
- valve positioners
- potentiometers and bridges

Table I shows the variety of bulletins on each of these subject categories used in the Seadrift program. Other instrument users follow a similar pattern, adapting to their own programs the literature of manufacturers whose instruments have been installed in their plants.

Formal training

The third and last phase of the Seadrift training is more detailed and formal. Classes again average about three and a half hours per week and the phase itself runs for about three years. Here, the student learns about:

- mathematics of instruments
- fundamentals of science
- basic instrument electricity
- electron tube basics
- blueprint reading and sketching
- introduction to shop practices
- tool and testing facilities
- pressure instruments
- flow measuring instruments
- liquid level instruments
- electrical instruments

The books in Table 2 are used for this more comprehensive and general training phase. These books have been employed successfully in the instrument maintenance training program of another large chemical manufacturer.

Bolster with training aids . . .

A most important part of the training program consists of the training aids made available both to trainees and instructors. They include study guides for the trainee, training guides for the instructors, a reference library, and a laboratory.

Study guides, one for each manual, help the trainee to pick up the salient information contained in the manuals.

Training guides, again one for each manual, aid the instructor in his presentation. They suggest points to emphasize, slides to show, experiments to perform, etc., so that the lesson can be put over clearly and logically.

The training laboratory familiarizes the trainee with process loops, control loops, trouble diagnosis in process and instruments, and instrument servicing. Figure 1 shows the training processes in the laboratory. These processes and their controls are described by Liford in the caption to this figure.

And keep on training

The degree of competence attained in training depends, to a great extent, on the trainees themselves. Native intelligence and ability, personality traits, attitude, and willingness to keep on learning and growing determine just how far up the promotion ladder the instrument maintenance technicians can go. At Carbide qualified men become group leaders; and some become engineering assistants in the instrumentation department. This opens up completely new vistas, with a new promotion ladder to travel. Some continue their training by going nights to engineering school.

But even the men who go no further than the instrument training program must continue to learn. "After these trainees have completed the last phase," explains Thomas, "they are then qualified instrument technicians. However, it is not expected that their training will stop at this point, since new techniques and methods are continually appearing in the field of instrumentation, and as these devices and techniques are used, the men will be given brief courses so that they will all be familiar with modern types of instrumentation."

HOW FORD MOTOR COMPANY TRAINS ITS CONTROL TECHNICIANS

TABLE 3—TRAINING TEXTS SELECTED BY FORD for teaching electricity, hydraulics & pyrometry

- Industrial Electricity, Nadon & Gelmine, D. Van Nostrand Co., Inc., New York.
- National Electrical Code, Pamphlet No. 70, National Board of Fire Underwriters, New York.
- Basic Hydraulics, No. 16193, Bureau of Naval Personnel, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.
- Simplified Industrial Mathematics, Wolfe, Mueller, & Mullikan, McGraw-Hill Book Co., Inc., New York.
- Electric Circuits & Machines, Lister, McGraw-Hill Book Co., Inc., New York.
- Hydraulics as Applied to Machines, Vickers, Inc., Detroit, Mich.
- Visualized Physics, Taffel, Oxford Book Co., New York.
- Fundamentals of Pressure and Temperature Instruments, Delmar Publishers, Inc., Albany, N. Y.
- Instruments and Process Control, Delmar Publishers, Inc., Albany, N. Y.

Hard-goods manufacturing enterprises, represented here by Ford Motor Co., require control technicians, too. Ford considers maintenance so important that it has established a separate Training Dept. for apprentices and journeymen as part of its industrial relations program. Courses run for four years. For an applicant to be eligible, he must have at least a high school diploma and technical aptitude.

Of the 24 courses in the apprenticeship group, three cover training of control technicians. These offer comprehensive instruction in industrial electricity, hydraulics, and pyrometry. Table 3 lists the books used in these courses. Graduates are well-grounded in their specialties and have a working knowledge of related technical activities in their plants. Their next step is to journeymen; after

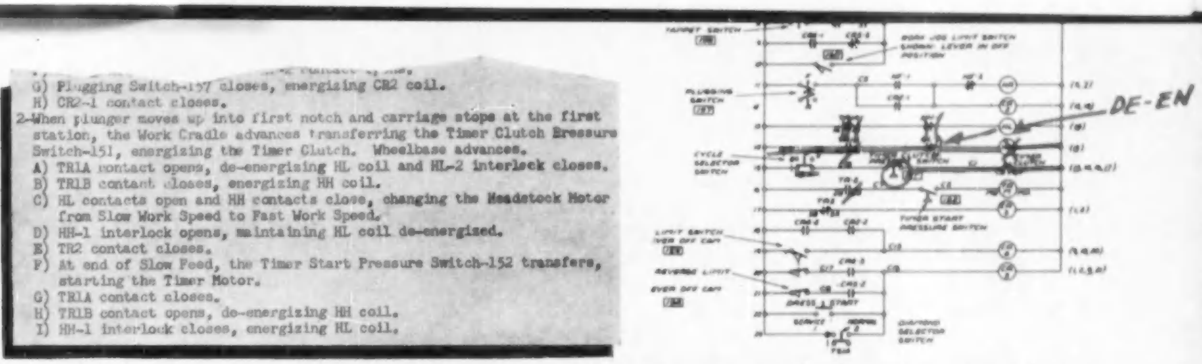


FIG. 2. Working with the detailed electrical sequence of operations for a cam contour and its associated schematic, prepared by Ford's Training Dept., the trainee traces, in color for emphasis, the circuits energized during one portion of the machine's grinding cycle. He continues in this manner until he is completely familiar with all electrical functions. He learns about hydraulic sequence in the same way.

which refresher courses keep them informed on latest developments.

Ford's refresher courses

These additional training courses familiarize experienced journeymen with new production machines, manufacturing techniques, control circuits, and maintenance methods. Courses run from 44 to 60 weeks. During this time the men attend classes for one or two full days per week and work at their regular jobs for the balance of the work week.

These programs reappraise skills and provide instruction in maintenance of the more advanced and complicated production machinery. Ford people say that new machinery replaces the old so rapidly that even three years may be too long a time between refresher programs if journeymen are to stay abreast of latest developments. This doubt becomes doubly understandable when it is realized that some of the machines cost well over a half-million dollars and produce many times their cost in useful goods.

Generally, a refresher course centers around special-purpose equipment, such as a completely automatic crankshaft manufacturing machine, or a class of machines, such as grinders. Visual aids and detailed instructions are prepared by the Training Dept. For instance, in tracing the control circuits of a cam contour grinder, the student uses master drawings of the hydraulic and electrical circuits. For each sequence in the machine's operation, he traces out on transparent overlays those circuits, components, and interlocks that are energized and functional. By means of different colors for the electrical and hydraulic circuits, he soon comes to understand the functioning of the machine so that he can rapidly diagnose and repair any trouble. The detailed instructions are shown in Figure 2 with a typical overlay developed by the trainee.

Ford also runs training programs for nonproduction personnel. One is a course in electronics given to Engineering Staff maintenance men. The 65 lecture sessions and five examination sessions run from electronics basics, such as static electricity and electrical units, to detailed discussions of commercial equipment, such as variable speed controls, dynamometers, and welding controls, employed in the engineering departments.

The electronics course begins with Ohm's Law, power, circuits, magnetism and inductance, ac and dc motors and generators, transformers, electrical meters, and color codes. After an exam, the trainee advances to basic tube functions, rectifier circuits, voltage multipliers, cold-cathode gas and mercury-pool tubes, operating principles of tubes, amplifiers, testing electronic equipments, electronic timers, and the amplidyne. Then comes another exam. Starting with the 26th session, his instruction centers on the equipment he will be called on to maintain. At

FIG. 3. Instructor William Zimmelman lectures on variable speed control circuits to a group of Ford Motor Co. employees studying electrical maintenance.

Ford's Highland Park, Mich., tractor plant this equipment includes: electronic controls for dynamic clutches, saturable core reactors and magnetic amplifiers, the General Electric Thyrotrol, several types of Reliance motor speed controls, GE inductor and dc dynamometers, Westinghouse dynamometers, welders, and Honeywell temperature controls.

Full use is made of training aids, as shown by the photograph (Figure 3) taken during one of the later course sessions. Here, the instructor discusses the principles of a motor speed control circuit, while on the table the controller and its components await a more detailed review. Typical of other training aids is the board in the upper right portion of the photo, which incorporates, for easy visualization, the actual components of a control superimposed on its circuit.

TRANSISTORS:
A New Class of Relays

When used in a common emitter circuit with their base terminals as the input electrodes, alloy junction transistors and surface barrier transistors behave remarkably like single-contact relays. This article shows, very simply, how they can take the place of these relays in logic networks and storage elements. In each case, the relay circuit is described first; then the corresponding transistor circuit.

These transistor circuits operate at very low power levels, which with their fast switching speeds makes them ideal for digital computer applications. By triggering sensitive relays or thyratrons, however, they can control conditional actions in higher-power control systems, too.

RALPH B. BROWN and RALPH H. BETER, Philco Corp.

Transistors can be used to advantage in place of relays in low-level signaling and switching applications, because the transistor can perform the same function as a single-contact, normally-open relay. With the transistor, switching power is negligible and switching speed is higher than any electromechanical relay can provide. Two types of transistors have been found to work especially well in relay-type circuits. One type is the alloy-junction transistor, with switching speeds in the 3-to-10-microsec range, and the other type is the surface barrier transistor, which is 50 to 100 times faster.

TRANSISTOR-RELAY ANALOGY

The form of the relay circuit in which a transistor might be placed is shown in Figure 1. The relay contacts are connected in series with a resistance and a battery. Obviously, unless the relay coil is energized by applying a voltage between coil terminal *b* and ground, the relay contacts will not close and no current will flow in the load resistance. Therefore, the voltage existing between point c and ground will be the same as the voltage supplied by the battery.

If a voltage is applied between terminal *b* and ground, current will flow in the coil, the relay contacts will close, and current will flow in the load resistance. The voltage measured between point c and ground will now be zero, since point c has been connected directly to ground through the relay contacts.

In the single relay switching circuit of Figure 1, the contacts will be closed when sufficient current is flowing in the relay coil, and will be open if little or no current is flowing in the coil.

The action of a transistor in a switching circuit is exactly analogous to the action of the relay circuit just described. However, before going into a discussion of the transistor switching action, it may be well to review the physical and electrical characteristics of the transistor itself.

The transistor is a semiconductor device with three terminals, one each for the base, the collector, and the emitter. Of the ways to connect to these terminals in a switching circuit, the most practical is to use the emitter terminal as a common terminal for both input and output. This arrangement, called the grounded-emitter configuration, provides more current gain than any other. The input terminals are base and emitter, and the output terminals are collector and emitter.

The transistor is basically a current-operated device. A small base current in the proper direction will control a much larger collector current in a grounded emitter transistor circuit. Such a circuit, shown in Figure 2, can be used as a current switch,

very much like the way the relay was used in Figure 1.

In the circuit shown in Figure 2 *b*, *c*, and *e* are the base, collector, and emitter terminals, respectively. Within the transistor are two diodes: one, formed by the base and emitter, has a low impedance-to-current flow in one direction and a high impedance in the reverse direction; the other is formed by the collector and base. However, a transistor is more than just two diodes, because its characteristics depend upon the interaction of the elements that make it up.

Normal operation polarites for the transistor are such that the base-emitter diode is biased in the forward direction, the direction of easy current flow, and the collector-base diode is biased in the reverse, or high impedance direction. This means that in normal operation of either surface barrier transistors or pnp alloy-junction transistors, both the collector and the base are connected to negative voltage supplies. The base current lowers the impedance of the collector circuit to the flow of reverse current so that a larger collector current can flow.

In Figure 2 the collector is connected to the battery's negative terminal through the load resistance, and the base-emitter diode is biased in the forward direction when a negative voltage is applied from the base terminal to ground. The direction of normal current flow in the transistor is indicated by the arrows i_c, i_b, and i_e. The emitter current in a grounded emitter circuit is equal to the sum of the collector and base currents.

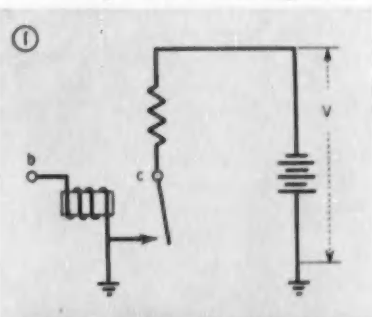
The current gain of a transistor is usually given in terms of α, in much the same manner as the voltage gain in a vacuum tube is expressed as μ. The alpha of a transistor is defined as the ratio of the change in collector current to a corresponding change in emitter current for constant collector voltage. This ratio is always less then 1.00 for junction and surface barrier transistors.

Another expression for current gain, known as β, is more useful in switching circuits. The beta of a transistor is defined as the ratio of a change in collector current to the corresponding change in base current for constant collector to emitter voltage. This ratio is usually much greater than unity. It is normally in the range 25.0 to 50.0, but it may be even higher. This means that if the base current in the usual grounded emitter transistor is increased by 100 microamp, the corresponding increase in collector current will be between 2.5 and 5.0 milliamp.

When no voltage is applied to the transistor base, no current will flow in the base circuit, and the collector-to-emitter impedance is very high. Under these conditions the transistor is essentially an open circuit. The voltage measured between collector and emitter is approximately equal to the supply voltage, since no current flows in the load resistance. If the base is energized by a negative voltage so

FIG. 1. Single-relay switching circuit

FIG. 2. Single-transistor switching circuit.



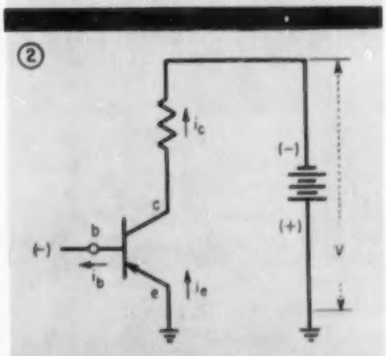
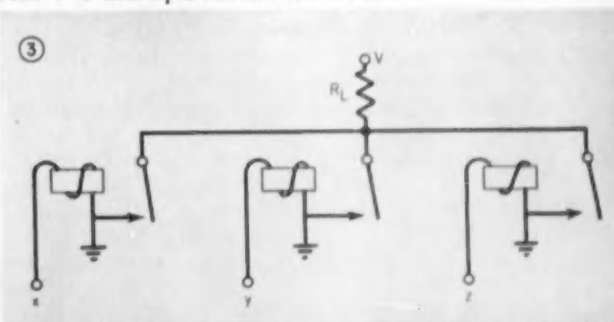
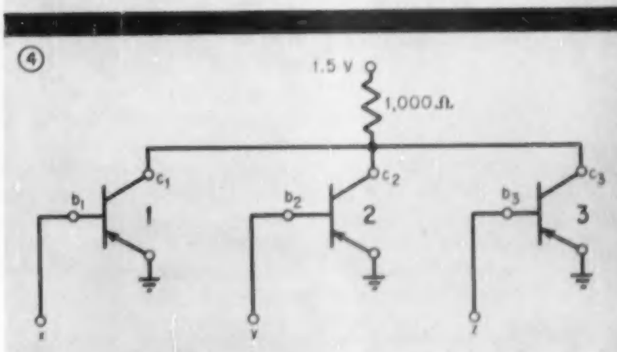


FIG. 3. A three-input relay OR circuit.

FIG. 4. A three-input transistor OR circuit.





that a forward base current flows, there will be a much larger current in the load circuit, and the collector to emitter voltage, due to the voltage drop across the load, will be practically zero. Note that this is exactly the same switching action that was obtained with the relay circuit of Figure 1.

The base terminal of the transistor corresponds to the relay coil terminal, the collector terminal to the ungrounded relay contact, and the emitter terminal to the grounded relay contact and coil terminal. The operation of the transistor is so similar to that of the relay that any relay of the type shown in Figure 1 may be replaced directly by a junction or surface barrier transistor and, providing the power rating of the transistor is not exceeded, the circuit switching operation will remain unchanged.

Use of the surface barrier transistor permits extremely fast switching operations. The time required to turn a surface barrier transistor switch "on" (to the state where large load current flows) is from 0.08 to 0.10 microsec. The time required to turn it "off" is slightly longer, being on the order of 0.10 to 0.12 microsec.

SIMPLE SWITCHING CIRCUITS

Perhaps the simplest type of switching circuit is one which performs a switching action if any one of two or more input conditions are satisfied. In terms of switching circuit "logic" this is called an OR circuit. A three-input circuit of this type, using relays as switches, is shown in Figure 3. It is easy to see that if any one of the three relay coils is energized, its contacts will close and current will flow in R_L, the load resistance. In fact, if a voltage is applied at x OR y OR z OR any combination of x, y, and z, the corresponding relay contacts will close and cause current to flow in R_L. In general, an OR function can be performed by two or more switches connected in parallel.

The three relays in Figure 3 may be replaced directly by three transistors with their emitters grounded, as shown in Figure 4. If transistors 1, 2, and 3 in this figure have no base current flowing, each collector-to-emitter path is equivalent to a very high impedance, and practically no current will flow in the load resistance.

If a small negative voltage, around 0.2 or 0.3 volt, is applied to the base of transistor 1 in Figure 4, the resultant base current will be between 500 and 1,000 microamp. Much more current than this may flow in the collector circuit of this transistor because of the current gain from base circuit to collector circuit. However, the supply voltage establishes a maximum value of about 1,500 microamp of current that can flow in the 1,000-ohm load resistor. As collector current increases toward this value the collector voltage decreases in magnitude and approaches ground potential. Actually, the current gain of a transistor decreases as the collector-to-emitter voltage approaches zero, so that the collector really never reaches ground potential. However, the collector to emitter voltage does decrease to approximately 0.02 to 0.03 volt, which is near enough to ground for switching purposes to be referred to as ground. The actual collector current flowing when transistor 1 is turned "on" is between 1,470 and 1,480 microamp.

If the base of transistor 1 is now deenergized, the base current will drop to zero, as will the collector current, permitting the collector potential to return to the supply voltage level. Obviously, the same result is obtained if any of the other transistors are turned "on" or if any combination of the transistors is turned "on". Again, this is exactly the same kind of switching actions as can exist in the relay circuit, since load current flows only when one or more of the relay coils (or transistor bases) are energized.

This OR type of circuit enables several independent signals of different origin to perform the same given switching function without the sources of the signals interacting. That is, each relay or transistor in an OR circuit acts as a buffer or isolating element.

A single relay or transistor acts not only as a buffer, but also as a signal inverter, in the circuits shown. That is, in the case of a relay driving a relay, energizing the coil of the first relay short-circuits or deenergizes the coil of the second relay. In the analogous case of a transistor driving another transistor, shown in Figure 5, turning transistor 1 "on" causes transistor 2 to be turned "off," and vice versa. An OR circuit also has the inverting property.

A second type of switching circuit is one which performs a switching action if, and only if, all the inputs (relay coils or transistor bases) are energized simultaneously. This circuit is called a coincidence or AND gate. A circuit of this type in Figure 6 uses relays as switches. This circuit shows that current can flow in the load resistance only when all three sets of relay contacts are closed, and contacts will be closed only when enough voltage exists across each of the three relay coils.

To study the operation of this AND gate, assume first that all three coils are energized and all the contacts in the gate are closed, and then that a relay coil, for example, the coil for relay 2, is deenergized. This will open the contacts of relay 2, which will break the ground-return path for relay 3's coil current. This will deenergize relay 3 and cause its con-

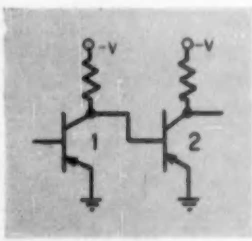
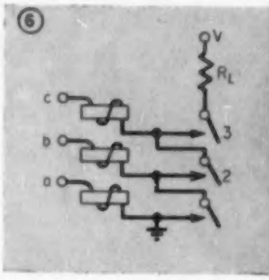


FIG. 5. Two switching stages in cascade behave inversely; 1 is "on" when 2 is "off", etc.



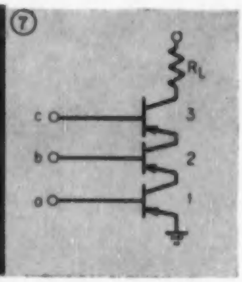


FIG. 6. Three-input relay AND gate.

FIG. 7. Three-input transistor AND gate.

tacts to open. In general, deenergizing any one or more of the three relay coils will break the grounding circuit through which the current through R_L must pass. In addition to carrying the load current, the contacts of each relay must also carry the current required to energize the coils of all the relays "above" it in the AND gate. It may be seen that load current will flow only if *all* the input terminals are energized simultaneously.

The transistorized AND gate can also be obtained by the direct substitution of transistors for relays. The action of the three-input AND gate for transistors, shown in Figure 7, is exactly analogous to the operation of the relay circuit. Assume that the base of transistor 1 is energized. Base current will flow, and the collector of transistor 1 will assume a potential essentially that of ground. If the base of transistor 2 is now energized, base current can flow since this current is now supplied by the collector current of transistor 1. Similarly transistor 3 can now be energized, and its base current will be supplied by the collector current of transistor 2. Note that in this circuit, just as in the relay circuit, each transistor must have sufficient collector current flowing to supply the demands of the load plus the current required by the bases of transistors "above" it in the AND gate chain.

Using the relay analogy, it will be apparent that the collector of transistor 3 will be at approximately the supply voltage potential at all times except when the three bases are energized simultaneously. Table I lists the voltage and current relations in a typical three-input AND gate with a supply voltage of -1.5 volts and a load resistance of 1,000 ohms. It has been assumed that for this particular AND gate, each transistor base required one-fifth as much current as its collector. This represents only a current gain of five from base to collector, and is lower than is actually realized in a gating circuit of this type.

Switching networks

Five relay networks are shown in Figure 8. In the network of 8A current will flow in the load only if x and y relay coils are energized, and in 8B current will flow in the load only when relay coil *x* is not energized and relay coil y is energized. In the circuit of 8D note that if relay coil x OR relay coil y OR if both relay coils x and y are energized, current will flow in the load resistance. Thus in general series arrangements of relay contacts produce AND logical functions and parallel combinations of relay contacts produce a logical function of OR.

In the circuit of 8D, the load will have current flowing in it if relay coil x is energized whether or not y is energized. The same applies if y is energized. More accurately, the expression for this circuit may be written as,

$$z = y(x + x') + x(y + y')$$

which may be expanded to the expression

$$z = xy + x'y + xy + xy'$$

Logically, this expression says that the load will draw current if there is x and y or y and not x or x and y or x and not y. Since $xy + xy = xy$, the expression for z may be simplified to

$$z = x'y + xy' + xy$$

If it is desired that no current flow in the load of the circuit of 8D when both x and y coils are energized, the circuit must be modified as shown in 8E. In this circuit, the load will be energized if either x or y is energized, but not when both x and y are energized simultaneously.

The relay circuit of Figure 8E may be used to present a kind of relay diagram "shorthand" notation. This is shown in Figure 9. The horizontal lines represent normally closed, or primed, contacts, and the diagonal lines represent normally open, or unprimed, contacts. The contacts shown in any particular column are all operated by the same relay coil. This notation is not limited to two relays. Each relay coil may also operate many normally-open and normally-closed contacts. However, since the transistor operates as a relay with a set of norm-

Table I

Typical currents and voltages in energized 3-input AND gate such as that of Figure 7:

TRANSISTOR 3:	
Collector to ground voltage	−0.09 v
Collector current	−1.41 ma
Base to ground voltage	−0.36 v
Base current	−0.28 ma
TRANSISTOR 2:	
Collector to ground voltage	−0.06 v
Collector current	−1.69 ma
Base to ground voltage	−0.36 v
Base current	−0.34 ma
TRANSISTOR 1:	
Collector to ground voltage	−0.03 v
Collector current	−2.03 ma
Base to ground voltage	−0.36 v
Base current	−0.40 ma

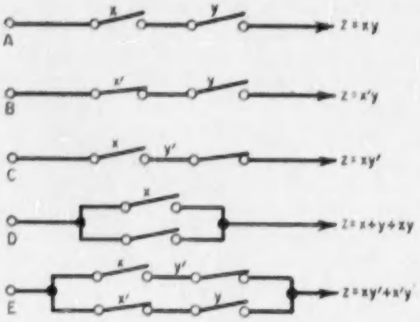
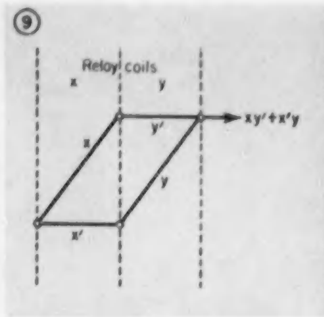


FIG. 8. Typical relay switching networks.



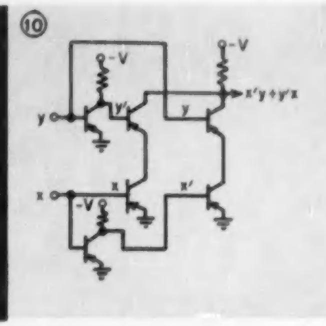


FIG. 9. Logic notation for two double-contact relays (circuit of Figure 8E).

FIG. 10. Transistor circuit for Figures 8E and 9.

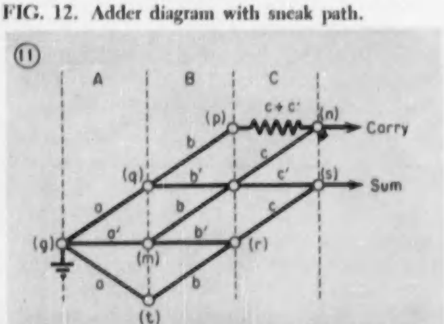
ally-open contacts, only relays of this type need be considered in the circuits.

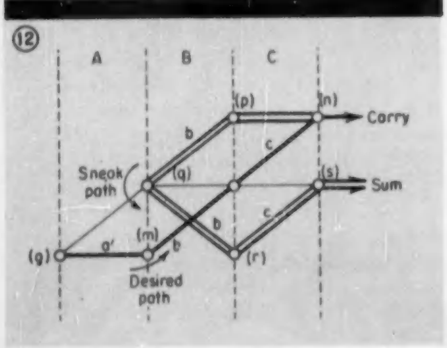
The input signal required by a normally-closed relay or its transistor equivalent is the inverse of the signal required by a normally-open device. In Figure 9, for instance, a signal that establishes a path through x must simultaneously break the path through x', and vice versa. A signal inverter of the kind discussed in relation to Figure 5 may be used to furnish this inversion.

Signal-inverting transistors are shown in Figure 10, which is a transistorized implementation of the diagrams in Figures 8E and 9. Obviously, if both the primed and unprimed forms of the input signals are available, no inverters are needed.

FIG. 11. Relay adder diagram.

FIG. 12. Adder diagram with sneak path.





Relay diagram shorthand sometimes requires a symbol to represent no-contact (that is, "shorting out") in one of the circuit paths controlled by a relay coil. Such a symbol is shown in the top horizontal line of Figure 11. This figure is a relay "adder" diagram, borrowed from digital computer work. The adder, a three-input gating network, generates a sum output if any one or all three (unprimed) input signals are present, and generates the carry output if any two or all three input signals are present. In generating a carry, therefore, if signals a and b are present it makes no difference whether c or c' is also present.

The validity of the relay-transistor analogy extends to some disadvantages of relays as well as to the advantages. One of the disadvantages is the possibility of "sneak paths" in relay-type networks. In relay work these paths occur because relay contacts, when closed, can conduct current equally well in either direction. The same applies to transistors, since the collector may act as an emitter, and the emitter as a collector, and the transistor will operate almost as well as in the normal, recommended manner.

The relay diagram of Figure 11, which does *not* have a sneak path, is redrawn in Figure 12 with a sneak path included to demonstrate what may happen in an actual circuit.

The effect of a sneak path may be understood first in terms of relay contacts. This particular sneak path causes a sum output to be generated when only a carry output is desired; for example, if the input conditions are $a'bc$. For this combination of inputs the path of conduction is as follows: starting at (g) to (m) to (n), a carry output is produced as required. However, since points (p) and (n) are connected by a short-circuit, the path continues from (n) to (p) to (q) to (r) and finally to (s), producing an unwanted sum output. In following this path, the current flowing in the contacts connecting (p) and (q) is reversed from the normal direction of flow.

In the transistor circuit for the adder of Figure 11, point (p) would connect to the collector of a transistor, and point (q) to the emitter of the same transistor. With signal *b* on the base, collector (p) held near ground, and emitter (q) connected through "on" transistors (q-r) and (r-s) to the sum output load resistor, current will flow through that transistor in a direction opposite to the standard direction. Transistors usually operate with current in the standard direction because in most transistors emitters are larger than collectors, an arrangement which produces more favorable characteristics.

STORAGE CIRCUIT

In all the circuits discussed so far, the output conditions are maintained only as long as the input conditions are maintained. That is, there is no storage, or remembering facility, for either the input or the output conditions. This implies that as long as any switching element is maintained in the "on" condition, the circuits doing the driving or energizing cannot be changed or used for other switching functions.

If some storage circuits, equivalent to mechanical toggle switches, are used to supply energizing signals to a switching circuit or network, control signals will be required from the signal-originating devices or circuits only during the time that the "toggle switches" are being set "on" or "off". These storage circuits will then maintain the "on" or "off" state indefinitely, making no further demand for energy, attention, or control from the signal sources.

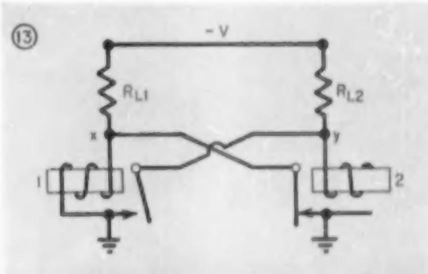
The signal-originating device may be some apparatus in which one or more sets of contacts are closed during a short interval of time. It is similar to a transportation system, where a vehicle establishes a connection when it passes a check point. The signals may also be derived from one of several "sampled" or time-shared devices. In either instance, if the signals must be maintained for a period longer than the time during which they are available, some form of storage must be provided for them.

Storage circuits may also be used to hold or preserve the output conditions of a switching network, enabling the network to be deenergized or to be used for some other application.

A storage circuit equivalent to an "on-off" toggle switch can be said to have a memory characteristic: that is, the circuit can "remember" one of two conditions. It is therefore a binary (two-state) memory or storage circuit.

A relay circuit having two stable states of operation is shown in Figure 13. This circuit can store a limited amount of information. In the figure, relay 1 is not energized and relay 2 is energized. The circuit point marked *x* is held at ground potential by the circuit path to ground established through the contacts of relay 2, thus bypassing to ground only current that might otherwise energize relay 1. Since the circuit condition can be changed only by some external influence, this represents one stable state for the circuit.

A second stable state, with relay 1 energized and relay 2 not energized, may be obtained if point y is connected to ground long enough for the contacts of relay 2 to open and relay 1 to close. Grounding point y deenergizes relay 2, opening its contacts and removing the short-circuit across the coil of relay 1. Relay 1 then becomes energized and its contacts close and short-circuit the coil of relay 2. When this



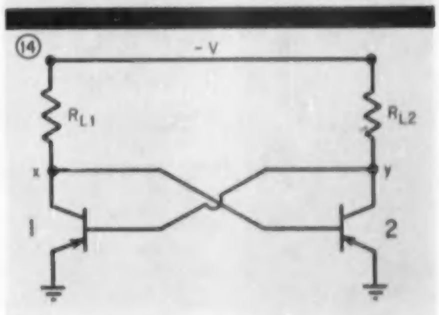


FIG. 13. Relay storage circuit (flip-flop).

FIG. 14. Transistor flip-flop.

happens, the temporary external ground applied to point y may be removed. The storage circuit will maintain this second stable state until it is forced back to the original state by temporarily grounding point x. This can be done by switching circuits, by single relays, or by contacts on some other device.

The transistor circuit analogous to this relay "toggle switch" circuit is shown in Figure 14. Assume in this circuit that transistor 2 is "on". A large base current will flow in load resistor R_{L1} and a large collector current in R_{L2}. The collector current is so large that the collector-to-emitter voltage of transistor 2 is almost zero, and practically all of the supply voltage is accounted for by the *IR* drop in R_{L2}. Since the collector of transistor 2 is tied directly to the base of transistor 1, transistor 1 is essentially cut off and it has very little collector current. This permits the base voltage of transistor 2 to rise negatively to a value determined by the value of R_{L1} and the input resistance of transistor 2. In this state, transistor 1 is "off" and transistor 2 is "on". This

Table II
Typical currents and voltages in flip-flop of Figure 14:

	"ON" transistor	"OFF" transistor
Collector to emitter voltage	−0.05 v	−0.35v
Collector current	−1.43 ma	−20 μa
Base to emitter voltage	−0.35 v	−0.05 v
Base current	−1.15 ma	−5.0 μa

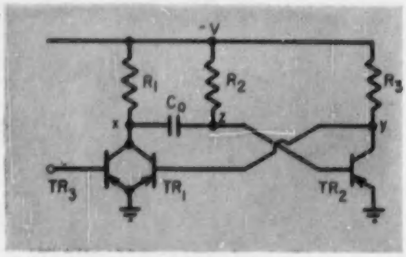


FIG. 15. Monostable transistor flip-flop.

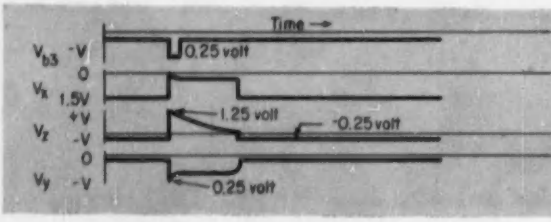


FIG. 16. Typical waveforms for circuit of Figure 15.

represents one stable state for the transistor storage circuit.

The second stable state can be obtained by temporarily grounding point x. This reduces the base current of transistor 2 to zero, causing that transistor to turn "off" and permitting the collector voltage of transistor 2 to increase negatively toward supply voltage. However, as the voltage on the collector of transistor 2 increases, the base of transistor 1 turns "on". A large collector current starts flowing in transistor 1 when the ground at x is removed, and the collector voltage therefore remains almost at zero. This voltage is low enough to keep the base of transistor 2 "off". As in the relay circuit, the transistor circuit may be forced back to its original state by temporarily grounding point y.

Binary memory circuits in general are known as flip-flops. The transistor circuit just described is called a saturation flip-flop, because one of the transistors is always in the high-current, low-collector-voltage region called saturation.

Typical values of operating current and voltage for this transistor flip-flop with —1.5 volts supply potential and with load resistances of 1,000 ohms are shown in Table II.

The voltage at the collector of the "off" transistor energizes the base of the partner transistor in the flip-flop, and is sufficient to energize the bases of several other transistors. Conversely, the "on" transistor collector voltage is low enough to turn "off" the base of any transistors connected to it.

Delay circuit

A flip-flop having only one rather than two stable states will provide storage for some definite period of time, rather than for an indefinite period. A monostable transistor circuit, sometimes referred to as a single-shot circuit or one-shot multivibrator, is shown in Figure 15. The value of resistance R_2 is chosen low enough so that transistor 2 is normally "on"; its collector-to-emitter voltage is therefore normally "off". The voltage at point x is near supply voltage —V, since no transistor base is connected to that point through a conducting path. The third transistor, TR3, may be used for the purpose of triggering the circuit.

A negative pulse applied to the base of transistor 3 causes its collector, and with it the collector of transistor 1, to rise in a positive direction to a voltage near ground potential. This positive pulse is coupled through C_0 to the base of transistor 2 and turns this transistor "off". The voltage at point y starts increasing negatively and turns transistor 1 "on". The pulse on the base of transistor 3 then is no longer necessary and may be removed with no effect on the cycle of operation. Since the positive voltage biases the base of transistor 2 in the reverse direction, transistor 2 remains "off" until the capacitor has discharged to the point where the base again goes negative and turns "on". The voltage at y decreases toward ground and transistor 1 is in turn cut off, allowing the voltage at x to return to a value near the supply voltage. Wave forms and typical values of electrode voltages are given in Figure 16.

The monostable circuit, using either relays or transistors, can prolong a signal that may originate, for example, as a momentarily closed set of contacts. These contacts may take the place of the triggering transistor, TR3. Once the contacts have closed and have grounded the collector of transistor 1, transistor 2 will go into its "off" state and delay the return of the TR1 collector voltage to its steady state value until at least a definite time later. Of course, if the external ground still exists at the TR1 collector when that transistor's base is returned to "off" the monostable circuit will not be able to affect the duration of the signal.

For time durations appreciably larger than the turn-on and turn-off times of the relays or transistors used, the signal-prolonging time of the circuit depends chiefly upon the values of R_2 and C_0.

FIG. 1

The "Early Bird" Goes Automatic

E. J. KOMPASS, Control Engineering

This is the story of the Southern Co.'s "Early Bird," an analog computer which will soon allocate load automatically to the generators on one of the country's largest electric power systems. It is the earliest known system-wide automatic incremental cost control in any industry. It is also among the earliest to include a computer and the system within its control loop. Southern's system certainly will remain one of the largest ever to do so: it is spread over 115,000 square miles and has a peak load of about 5 million horsepower.

The old adage about the "early bird" apparently still applies if the "Early Bird" happens to be an analog computer. For over two years now, a computer of this nickname has been saving money at rates averaging \$25 per hour. On a 24-hour-a-day basis, this amounts to more than \$200,000 per year. The Early Bird, shown in Figure 1, is the brainchild and namesake of E. D. Early, manager of the Southern Co. Power Pool. It continuously calculates the most economic distribution of loading on one of the nation's largest electric power systems.

The computer is of interest to control engineers for two reasons. First, it is a working example of the improvement possible in manual control simply by preparing raw data for the operator with automatic (data processing) computers. The Early Bird gets some of its data by analoging parts of the system that it monitors, but it measures the important parameters directly by telemeter. Second, it will soon be an operating example of an optimizing computer in a closed-loop control system. Its design has proceeded from the beginning with system control by the computer as the objective.

The system in point includes the power generating plants and transmission lines of the Southern Co. system, which consists of the Alabama, Georgia, Gulf, and Mississippi Power Co. The Southern Co. serves in four states (Gulf Power Co. in the Florida panhandle), covers 115,000 square miles, and has a pe[illegible]mand of nearly $3\frac{3}{4}$ million kw. About 3 mil[illegible] are generated by steam plants, the other 1 [illegible]on by hydroelectric plants. The system is tied in[illegible]ith nearly 40 million kw of generating capacity

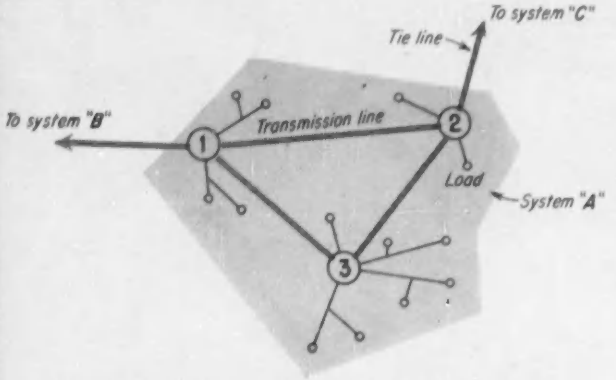


FIG. 2. Typical three-station power system showing loads, transmission lines between stations, and tie lines to other systems.

made up of TVA to the north and northwest, Mid-South to the west, and Florida Power to the south.

Two of the hydroelectric plants in the system are equipped with Leeds & Northrup automatic tie-line frequency-bias load control systems [1]. At any time, one of these plants is the regulator for the entire system. Net interchange of power over the tie lines to other systems is the basic control parameter; frequency is monitored and reset as necessary. Assuming frequency to be constant at 60 cps, the net power interchange over the tie lines should equal the power scheduled to be transferred to or from other systems. Thus, if no power is scheduled to be transferred with other systems, the net power interchange over the tie lines should be zero. It will be zero only if the system is exactly carrying its own load. Therefore, algebraic summation of power at all tie-line interconnections is all that is needed to determine that the system is meeting its own load requirements. A typical system is shown in Figure 2.

Because of their phase characteristics, ac generators must run in synchronism; thus frequency is the same over an entire connected network whether or not power flows over tie lines. If in a connected network one system generates power in excess of its own load requirements, and all other systems exactly carry their own loads, the excess power goes into rotating energy (termed "spinning storage"), raising network frequency. On the other hand, if one system fails to carry its own load, the energy required by the load is supplied from the spinning storage, and the frequency decreases. If the frequency is low, the additional generation needed to restore frequency should be supplied by the low system. To be sure of this, each system comprising the connected network is assigned a "frequency bias" of so many megawatts per 0.1 cps deviation in frequency.

If a particular system has a frequency bias of 35 Mw per 0.1 cps and is properly carrying its own load when frequency decreases by 0.1 cps, 35 Mw should flow out over its tie lines and no change in generation should be necessary. If only 30 Mw are contributed to the network, generation must be raised by 5 Mw, indicating either that the system's bias assignment is 5 Mw too high or that its load has increased by 5 Mw. The fact that power flows out when frequency is low indicates that some other system has failed to carry its load, and no generation should be added locally if the frequency bias is met. Power flow in over the tie lines when frequency is low indicates failure to carry local load, and power must be raised enough to equal the tie-line schedule plus the frequency bias. This amounts to over-generation, putting energy back into spinning storage and raising frequency. Frequency-bias generation decreases to zero as frequency comes back to the set-point, and tie-line power comes back to tie-line schedule over the entire network.

If the frequency is high, power flows from the system that is over-generating to the systems that are on schedule in proportion to their frequency biases. This indicates that the high system must reduce its generation.

Because of the large amounts of inertia in the spinning storage of large power networks, system frequency varies essentially as the time integral of the connected companies' failure to maintain their scheduled tie-line loads. The time-keeping quality of electric clocks depends upon the power networks' maintaining a precise average 60 cps. A master electric clock is kept within seconds of the National Bureau of Standards' time transmission by manually varying the frequency set point so as to make the integrated error zero.

The discussion so far has shown how the Southern Co. system operates within a larger network of connected power systems by maintaining its tie-line loads and its contributions to network frequency according to otherwise determined schedules. With the system's total generation thus determined, it now becomes necessary to apportion this load among the various generating stations of the system.

Plant loading methods

The distribution of system load among the generating plants on the system must take into account many factors: unit generating capacities, maintenance schedules, fuel costs, boiler heat rates and efficiencies, water availability, etc. The Early Bird

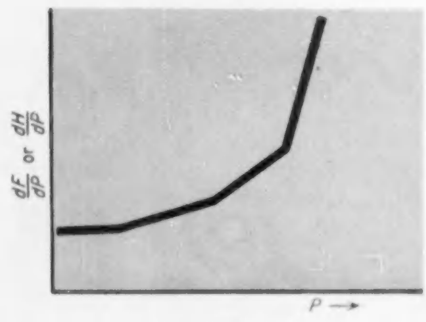


FIG. 3. Typical heat-rate curve for a steam generating station. Incremental generating cost dF/dP is related to incremental heat rate of dH/dP by fuel cost.

AUTOMATIC ECONOMIC LOADING CONTROL

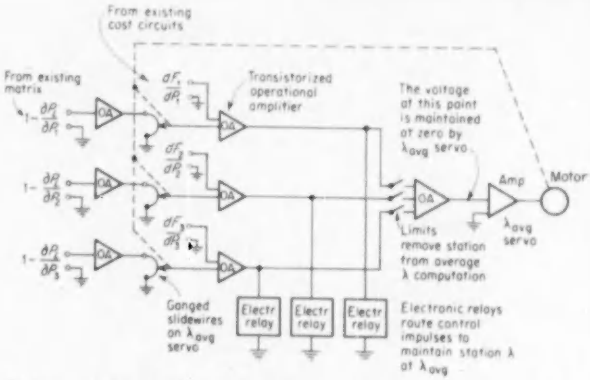


FIG. A. Automatic incremental cost control.

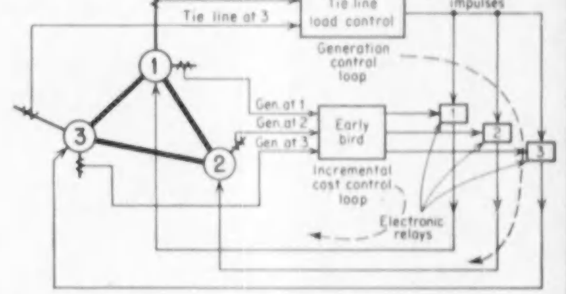


Fig. B. Early Bird operates within the load-frequency loop.

The Early Bird was planned from its conception to load the generating stations of the Southern Co. system automatically in conjunction with the tie-line frequency-bias load control system. It was decided to build the original unit without this feature until the computer had proven itself satisfactory in actual operation. The automatic loading control is now being added, and the entire system should be in operation in a few months.

In power systems, the condition for economic system loading requires that the incremental cost of delivered power for each station be equal to the average incremental cost of delivered power for the system. Mathematically,

$$\lambda_n = \lambda_{avg} = \frac{\dfrac{dF_n}{dP_n}}{1 - \dfrac{\partial L_n}{\partial P_n}}$$

Thus, for each station, the automatic loading control must solve the following equation:

$$\lambda_{avg}\left(1 - \frac{\partial L_n}{\partial P_n}\right) - \frac{dF_n}{dP_n} = 0$$

How this will be done is shown by Figure A. The output of the Early Bird's transformer-resistance matrix, $(1-\partial L_n/\partial P_n)$, for each source is connected to a unity gain isolation amplifier, which supplies a slidewire whose arm is positioned by a new servo that calculates λ_{avg}. The incremental generating cost is subtracted from the output of this slidewire in a second operational amplifier for each source. The output of this second operational amplifier will be zero only if λ_n is equal to λ_{avg}. This output is summed with the same output from all the other sources in the input to the λ_{avg} servo, completing the loop.

As noted, the output of the second operational amplifier for each source should be zero if the system is operating economically. Each of these points is monitored by an electronic relay that closes one set of contacts if the incremental delivered cost for that station is too high, and closes another set of contacts if it is too low.

Figure B shows how these electronic relays controlled by the Early Bird will automatically route the control impulses from the load-frequency controller to the proper generating station to maintain economic loading. Note that the automatic Early Bird is only a signal routing system. Load and frequency are still the basic control parameters.

is daily proving that power losses on transmission lines should also be taken into account, at least for large systems with long transmission distances.

Because the heat-rate curve of a steam generating plant is nonlinear, Figure 3, generating costs must be calculated on an incremental basis. As noted previously, one hydroelectric station carries the minute-to-minute variation in system load to maintain the system's tie-line schedule and frequency. The hydro station might be carrying the top 100 Mw of a total 2,500-Mw system load. The other 2,400 Mw are supplied as a constant base for the hydro station by the other generating plants in the system.* If the system load increases so as to exceed the capacity of the hydro station, its operating base must be raised by adding generation at one of the other plants in the system.

For example, the plant presently operating at the lowest total cost per megawatt may have a higher cost for an additional 5 Mw of power than some other plant in the system. Thus, generating plants should be loaded on the basis of incremental generating costs rather than actual costs.

Except for certain large nonconforming loads, such as steel rolling mills, total system loads follow

In the Early Bird system, Southern's many generating units—44 steam and 18 hydro—are treated in combinations of like steam units. There are 28 such combinations, and these are the 28 generating "stations" loaded by the Early Bird.

FIG. 5. Special transformers with 30 secondaries add trans-

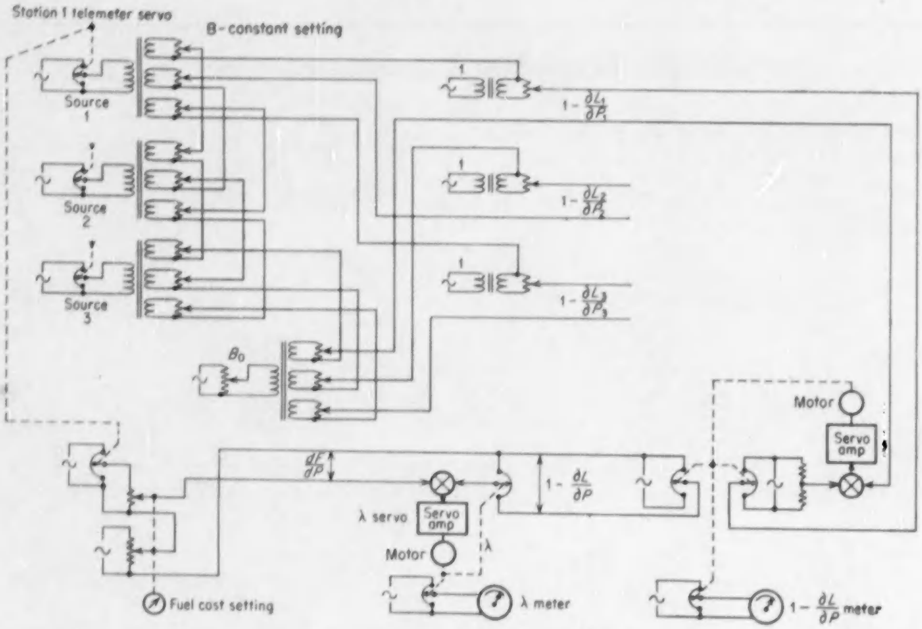


FIG. 4. Simplified diagram of Early Bird as it would look for only three sources.

a more or less predictable day-to-day pattern, and until a few years ago were scheduled 12 to 24 hours in advance by the Power Pool Office. These schedules, however, were seldom followed exactly because of the many variables in system operation which cannot be forecast, even a few hours in advance. In 1952 the Central Power Coordination Office was established and put under the direction of Don Early, who had been managing the Power Pool since 1949. Station loading was still on a block loading schedule, and Early was studying the analysis of power systems in the evening.

Early recognized that loading of units for maximum economy at the generating plants was not the correct answer, in that the effect of transmission losses was not reflected in such operation. Total cost of power supply is determined by the cost of power at the load centers and not by the cost at the generator bus.

The effect of transmission losses upon the cost of power delivered was first studied by E. E. George of Ebasco Services, Inc., in 1943[2]. In 1950, Eaton, Ward, and Hale of Purdue placed the determination of transmission losses upon an analytical basis[3]. And by 1951 Kirchmayer and Stagg of General Electric had used tensor methods to anlyze the American Gas & Electric Co.'s system[4], and showed that the minimum cost of system power supply is attained when the incremental cost of delivered power is the same for all sources.

The incremental cost of delivered power for a particular station is that station's incremental generating cost divided by the percentage of the incremental generation that it delivers to the load center. Incremental generating cost is the slope of the generating cost vs. power curve for the station, that is dF/dP. The percentage of generation delivered is simply one minus the incremental transmission losses from the station to the load center, or $(1-\partial L/\partial P)$. Thus, the incremental cost, λ_n, of delivering power to loads from station n, is

$$\lambda_n = \frac{\dfrac{dF_n}{dP_n}}{1-\dfrac{\partial L_n}{\partial P_n}} \qquad (1)$$

The incremental losses with respect to station n are expressed as a partial derivative because they are calculated for a change in the power of station n only, all other station outputs being held constant.

The total transmission losses for an entire system can be expressed as

$$L_T = \sum_m \sum_n P_m B_{mn} P_n$$

which is the sum of the transmission losses from each station m of n stations to the load centers. This is an equation of n^2 terms. Note that for a system of two stations the transmission losses are

$$L_T = P_1^2 B_{11} + 2P_1P_2B_{12} + P_2^2B_{22}$$

In this case the terms $B_{11}P_1^2$ and $B_{22}P_2^2$ represent losses when the entire load is supplied by station 1 or 2 respectively, and the mutual term $2B_{12}P_1P_2$ represents the adjustment in losses when the load is supplied jointly by stations 1 and 2. In this case the mutual constant B_{12} would probably be negative, which is usually the case for mutual constants although they may be positive for stations that are electrically close to each other.

For the two-station system, the incremental transmission loss with respect to station 1 is

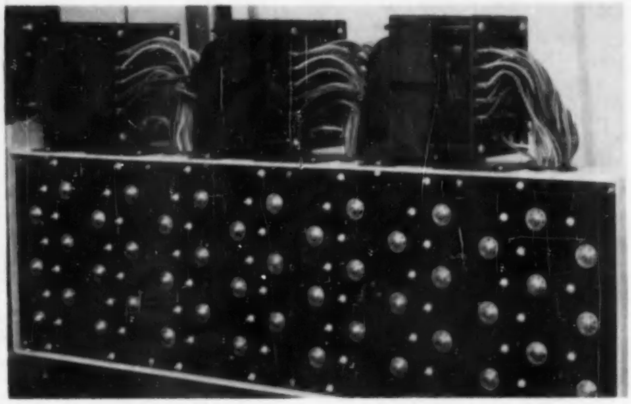
$$\frac{\partial L_1}{\partial P_1} = 2B_{11}P_1 + 2B_{12}P_2$$

and with respect to station 2 is

$$\frac{\partial L_2}{\partial P_2} = 2B_{22}P_2 + 2B_{12}P_1$$

For the general case of n stations, the incre-

FIG. 5. Special transformers with 30 secondaries add transmission losses. Half the B-constant pots for the three transformers are visible. The other half are on opposite face There are ten of these assemblies (30 transformers) in the Early Bird.



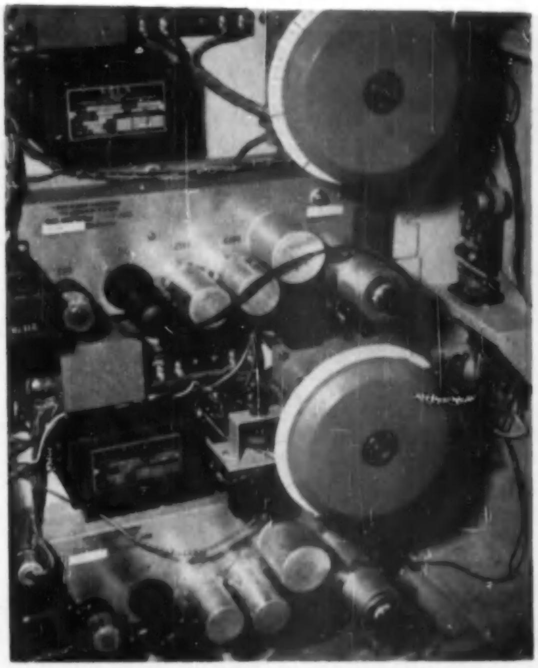


FIG. 6. These two servos calculate the incremental cost of delivered power and the percentage of power delivered for the generating station chosen by the operator.

mental transmission loss with respect to station n is

$$\frac{\partial L_n}{\partial P_n} = \sum_m 2P_m B_{nm} \qquad (2)$$

A station's generating costs are related by the cost of fuel to the station's heat-rate characteristics. These vary nonlinearly with power because of the no-load heat loss, and because the efficiency of the station varies nonlinearly. Thus, economic scheduling of generation among the 28 stations of the Southern Co. system requires solution of 28 simultaneous equations like that for λ_n (Equation 1). Each of these equations is nonlinear and contains an implicit equation of 28 terms in its denominator.

Enter the computer

When Early started his study, American Gas & Electric was already making use of the transmission loss equations (Equation 2). They had solved them for certain representative load distributions on their system, using the Kirchmayer and Stagg[2] B-constants. Curves were drawn by interpolating between calculated points. This method requires families of curves for variations in system power level and stacks of families for variations in load distribution. Inclusion of other variables, such as the changing costs of fuel at particular generating stations, adds more dimensions to these stacks. At best, the cost of preparation of such charts is high, and they are only of value as long as the system remains the same. Changes in the system, such as construction of new plants or new transmission lines, would require recalculation of the entire set of charts.

While American Gas & Electric could find few-enough representative load conditions to make such a solution economically worthwhile, Early did not believe that it would be practical for the Southern Co. system. Southern has dump gas contracts for certain of its plants. Dump gas is cheap fuel, but it must be consumed as soon as it is available. Availability can vary from full plant output to zero. Southern also has a relatively large number of interconnections with other systems over which power is bought and sold, and a large number of hydro plants in which "fuel cost" is an arbitrary variable that depends upon the amount of water in storage for future load peaks. All of these things mean an almost infinite number of "typical" system conditions.

What was needed was an automatic computer that would continuously solve the equations for the conditions currently existing on the system. In this way, the operator would know at all times which unit should take the next increment of load. Early recognized his company's need for such a computer and undertook its design evenings after work. This was his "hobby" for the next year.

He first considered a computer using a complete analog of the power system. Computers of this type have recently been built for the West Penn Electric Co. by Westinghouse and for the Ohio Edison system by Goodyear Aircraft. These two computers were placed in service during the summer of 1956, more than two years after the Early Bird was placed in service. One difference between these two computers is that West Penn's uses a direct analog for a station cost curve which is a composite of the cost curves of the various generating units in that station, while Goodyear's analogs each unit individually and obtains the station cost curve by averaging. American Gas & Electric, in the meantime, working with General Electric Co., was developing its Penalty Factor Computer. This was installed at Columbus, Ohio, in 1955. The "penalty factor" here is $1/(1-\partial L/\partial P)$, that is, the reciprocal of the percentage of power delivered. This penalty factor is computed automatically for each station. It is multiplied on a special slide rule by the incremental generating cost

for that station, which is set in by hand. Though the result is the incremental cost of delivered power, the process is quite slow if such costs must be compared for a large number of stations to determine economic loading.

Early was disturbed by the concept of a complete analog for a system as large as the Southern Co. He could see too many maintenance and reliability problems. Then he had an idea: determine only the incremental cost for each station and make the indicated changes in each plant until each plant comes to the same average incremental cost of all plants. By this scheme, the entire system is then in the feedback loop, and it is not necessary to devise a complete analog of the power system. To solve the λ equation in this way it is only necessary to analog the incremental generating cost curves for each station, and the various B constants as determined from network analyzer studies of the system under various conditions. The only system inputs are the power flows that exist at the generating stations and tie lines of the system.

By the time Early started his design, Alabama Power Co. has already been telemetering to its dispatcher's office for at least eight years the power flows over four tie lines to TVA and the generation at two regulating hydro stations. When the Central Coordination Office was set up by Southern Services, four more power readings were telemetered in from the Georgia Power Co. There were plans to add more telemetering. Early went ahead with his design with the understanding that continuous power measurements from tie lines and generating stations would be available to his computer via telemeter.

It was during installation in February 1953 of more telemetering equipment that Leeds & Northrup engineers first got wind of Early's computer. In March of 1953, L&N offered to build the computer on an experimental basis and underwrite the cost of further development. By this time, Early had the computer completely designed in principle. It remained only to iron out certain circuit details—scaling, impedance-matching problems, special component designs, etc. But the design so far was on paper only. Early had built no breadboards.

Early had also worked out a method of calculating the B coefficients of the incremental transmission loss equations from the results of network analyzer studies. He now applied this to network analyzer studies of the Southern Co. system for about 32 different conditions. He found that the loss coefficients varied too much. At first he thought that his computer design was inadequate, but further study indicated that the principal errors lay in one of the assumptions made in the derivation of the original loss equations.

The original deviations by George, et al. [2,3,4] assumed that the load at each station varies between zero and full load as the total system load varies between zero and full load; i.e., that each station load remains a constant percentage of the total system load. By this assumption the system load pattern remains unchanged as the total system load changes. Since, on most systems, there is a substantial variation in the load factor of various areas, depending on the type of load supplied, industrial, commercial, or residential, and on the type of industrial load, station loads do not usually vary as a constant percentage of system load. Early found it necessary, at least for the Southern Co. system, to modify this assumption so that each station load would be assumed to vary linearly between its minimum and its maximum as the total system load varies between minimum and maximum.

Early's new assumption permits the station loads to vary at different rates as a percentage of total load. Extrapolated to the extreme condition of zero system power supply, something never encountered in practice, this assumption requires that there be transmission losses when all of the generating stations on the system have zero output. Mathematically, this means that if the station loads vary by given (though different) rates even after they have become zero, the loads must become negative one by one. Because negative loads are power sources, no generation is required from the generating stations when the negative loads balance the positive loads. But there are still transmission losses in such a system. Thus, this new assumption requires the addition to the transmission loss equation of another loss constant, B_{n0}, representing the incremental loss of each source under the condition of zero system power supply[5,6]. The new loss equations look like this:

$$\frac{\partial L_n}{\partial P_n} = \sum 2B_{nm} + B_{n0}$$

$$L_T = \sum_m \sum_n P_m B_{mn} P_n + \sum_n B_{n0} P_n + K_{L0}$$

This condition of zero system power supply can never actually exist, and was defined solely to determine these constants. The addition of these new terms, however, made the errors in the loss equation insignificant when calculated for the 32 typical system loading conditions set up on the network analyzer.

The Early Bird

Figure 4 shows a simplified form of the Early Bird computer as it would look for only three sources. This diagram does not include the automatic incremental cost control equipment which is presently being added. The computer's outputs are meter readings representing the incremental cost of *delivered* power, λ, and the percentage of power delivered, $1-\partial L/\partial P$, for each of the generating sources. Its inputs are voltages representing the powers actually existing at these three generating stations as measured and telemetered to the computer. The voltages are derived from auxiliary slidewires positioned by the telemeter indicator servos.

The Early Bird is an ac analog computer. The

incremental transmission losses for each source are computed by the transformer-resistance matrix at the upper left. In the actual Early Bird there are 30 specially-designed transformers; each of which has 30 secondaries. (Figure 5). Each secondary is shunted by a potentiometer, which is adjusted to give an output representing the source output times the applicable B constant. For example, the top secondary of source 1 develops a voltage representative of the output of source 1 times its self-constant; the same secondary of source 2 develops a voltage representing the output of source 2 times the mutual constant between source 1 and source 2; the same secondary of source 3, a voltage representing the output of source 3 times the mutual constant between source 3 and source 1. These secondary voltages are summed by series addition. The output of source 2 is reversed because its B constant is negative. This sum is the incremental transmission loss of source 1. It is then subtracted from unity to give the percentage of power delivered.

The incremental transmission losses are summed at a high impedance servo input. This servo drives two auxiliary potentiometers, one of which supplies the percentage-of-power-delivered meter. The other potentiometer provides an input for the λ servo, which divides the cost of generating power at a given unit by the percentage of power delivered.

The power being generated at each source (by means of a second auxiliary slidewire on each telemeter indicator servo) is multiplied by a constant that represents fuel cost (the upper manually-set pot) and is added to a constant that represents the zero-load intercept of the incremental cost curve (the lower manually-set pot). In Figure 4 the fuel cost function varies linearly with power generation. In the actual computer, the slidewire is tapped and loaded externally with resistors to approximate the shape of the station heat-rate curve (see Figure 3). The incremental generating cost dF/dP thus obtained is the second input to the λ servo.

Automatic loading control

Remember that the primary loading control is the tie-line frequency-bias regulating system. This operates continuously to maintain the system's net interchange schedule. The deviation from the net interchange schedule is called the system's "area requirement". It is the amount of generation that must be added or dropped on the system to return to schedule. The "area requirement controller", a zero-center recording instrument, is the master controller for the system. Its output is a series of pulses on either of two lines. Impulses on one line are signals that generation is to be raised; on the alternative line, that it is to be lowered.

At present, these raise and lower impulses are sent to the regulating hydro stations. This is not good economic use of the hydro facilities. Water is used at all times for regulation when it might be more economic to save it for peak load conditions when the incremental cost from the steam plants is high. Automatic controls are now being built for the steam stations. When the cost control system is installed, the hydro plants will no longer be the regulating stations for the system.

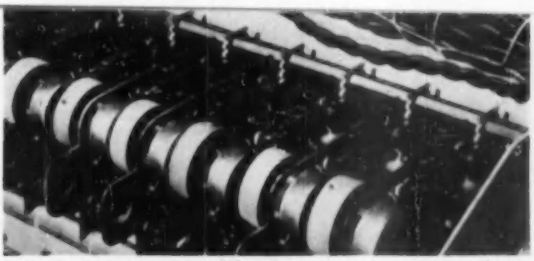


FIG. 7. Operational amplifiers for automatic cost control now installed for testing are transistorized, have printed wiring.

In the cost control computer, Figure A, the impulses from the area requirement master controller will be routed via the electronic relays to the generating stations that are out of line with the average incremental cost. Stations that are high cannot receive raise impulses, and stations that are low cannot receive lower impulses.

It should be noted that certain stations will have incremental costs well below the average for the rest of the system. These stations will operate at full rating most of the time. Stations that are at their limits or not in their regulating range for any reason are left out of the average cost computations.

Stations within their regulating range are presently held within 0.1 mill of the average incremental delivered cost per megawatt-hour by closing the loop manually through the operator. Automatic control is expected to reduce this deviation by a factor of five.

Reliability

There are only two moving parts (the servos) and eight electron tubes in the Early Bird at present. All the new electronic equipment being added for the cost control computer is transistorized, Figure 7. A gasoline-powered generator stands by on the roof to supply the computer in case of power failure in the building in which it is housed. The auxiliary generator is tested weekly. All the rest of the components in the system are static. The total power consumption for the equipment is only 250 watts at present, and will not be much more when the cost control is added because of the transistorization.

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Stabilizing Instrument Servos by Internal Motor Damping

GERALD WEISS, The W. L. Maxson Corp.

THE GIST: The servo stability problem has been treated exhaustively in the literature, and elaborate and complete design procedures are available. However, most servo problems do not require such advanced design methods. One common type of servo is a simple positional servo, used in remote indicators. In this and many similar applications, the damping inherent in the servo-motor is sufficient for servo stabilization.

To achieve desired performance some stabilization means must be provided in every servo[1]. Where the dynamic accuracy requirement is low, viscous damping can be used. This can be obtained by three basic methods: viscous output dampers, tachometer feedback, or internal servomotor damping. The first method reduces available motor torque and is not commonly used. The second method can be used wherever much viscous damping is required, particularly where static accuracy is high or the natural frequency is low[2]. The third method, cheapest because it requires no extra equipment, can be used where the static accuracy is moderate.

Tachometer-damped servos often can be built with a minimum of design, after which amplifier gain can be adjusted for desired static accuracy and tachometer output adjusted for desired damping ratio. But not so in a servo using inherent motor damping, where there is only one adjustment—amplifier gain. Here, if the "build-it-without-design" technique is used, adjustment of the gain for proper static accuracy may yield too low a damping ratio, and the servo must be rebuilt. The following outlines a procedure that insures sufficient inherent motor damping and satisfactory operation in the design stage.

The output torque of a servo with a negatively-sloping straight-line torque-speed curve, Figure 1, has two components: a constant torque T_M, and a negative torque proportional to speed. The latter component constitutes viscous damping[3], making the slope of the torque-speed curve the damping coefficient, expressed in units of torque over speed. This desirable negative slope is typical of the speed-torque curves of a two-phase induction motor, used as the actuator in ac servos, Figure 2[4]. The problem is to compute the damping coefficient, since the various curves are not linear and not parallel. The correct slope to use is the zero-speed slope of the zero control-field voltage curve, because small servo oscillations take place around the zero-speed/zero-V_{CF} point.

If a complete set of characteristics, similar to those shown in Figure 2, is supplied by the motor manufacturer, the damping coefficient K_F can be obtained by scaling the slope of the correct curve. Usually, though, the manufacturer furnishes only the torque-speed curve for balanced operation (control-field voltage, V_{CF}, equals main-field voltage, V_{MF}). But then the zero-speed slope of the zero-V_{CF} curve can be obtained from the following[5]:

$$M_c = \frac{M}{2} \tag{1}$$

where M_c = slope of zero-V_{CF} curve at zero speed
M = slope of balanced-excitation curve at zero speed

Often the manufacturer does not provide a torque-speed characteristic for balanced excitation, but merely gives values for the stall torque T_M and the maximum speed N_M. The damping coefficient can then be approximated by

$$K_F = \frac{1}{2}\,\frac{T_M}{N_M} \tag{2}$$

The K_F obtained from Equation 2 is always too large, because the torque-speed curves are always concave downward. To obtain a more conservative and correct K_F it is customary to use synchronous speed N_S, rather than maximum speed. Then

$$K_F = \frac{1}{2}\,\frac{T_M}{N_S} \tag{3}$$

Some manufacturers' catalogs give values of damp-

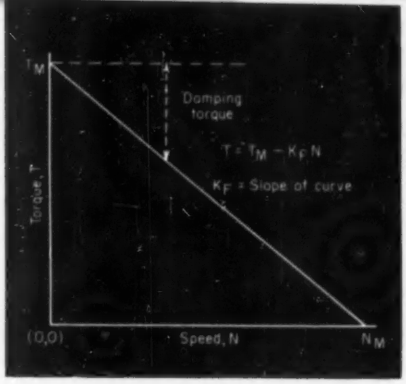

FIG. 1. Torque-speed characteristics of a viscous-damped servo.

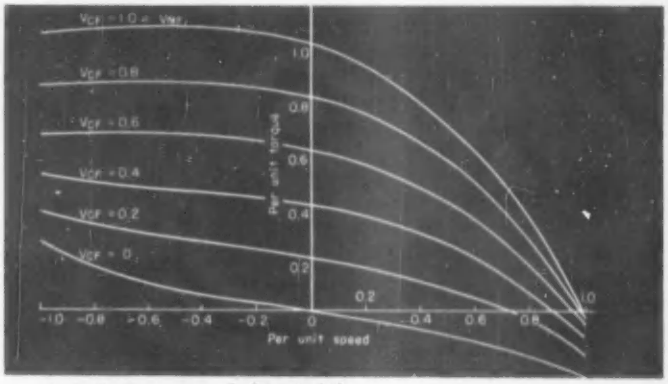

FIG. 2. Torque-speed characteristics of a two-phase induction servomotor.

ing coefficient based on the formula K_F equals T_M/N_S. This leads to incorrect answers. Manufacturers also classify their motors according to the ratio of torque to inertia. Design for maximum inherent motor damping actually leads to a maximum value of the ratio of torque-squared to inertia, and motors should be compared on that basis[5].

The set of curves shown in Figure 2 applies to a motor energized from a zero-impedance source, a source that delivers a speed-independent voltage to the motor windings. This is not generally the case. In a servo, the control-field winding is energized from an amplifier. The servomotor input impedance increases with increasing speed. The amplifier output impedance makes the motor torque-speed curves more concave and lowers the zero-speed slopes, consequently reducing the damping. Thus, in a servo stabilized by internal motor damping, the amplifier output impedance must be kept low by a sufficient amount of negative feedback around the amplifier, or at least around its output stage. A feedback ratio of at least 5:1 is recommended.

Even if the viscous damping from the servomotor is neither required nor desired, servo amplifier output impedance should still be kept low. Excessive source impedance causes the motor torque-speed curves to peak, like the curves of large induction motors used in power applications. A motor with a peaked characteristic may "single-phase", i.e., develop torque with zero control-field voltage. This makes the servo unstable.

Servo analysis

A positional servo can be represented by the block diagram of Figure 3. For a simple instrument servo of low dynamic accuracy, the various components can be assumed to be linear, and higher-order time constants can be neglected. The servo then can be described by a second-order equation, analogous to the equation of a spring-mass system in mechanics, or to the equation of a resonant circuit in electricity. This analogy is used to analyze the servo, without recourse to elaborate servo theory. As always in such systems, two basic quantities can be defined; the undamped natural frequency ω_o and the damping ratio ζ.

Assuming the block diagram of Figure 3 represents a second-order servo, and neglecting nonlinearities, the undamped natural frequency and damping ratio can be expressed by the following:

$$\omega_o = \sqrt{\frac{K_T K_A K_E}{Ja}} \tag{4}$$

$$\zeta = \frac{K_F}{2}\sqrt{\frac{a}{J K_T K_A K_E}} \tag{5}$$

and ω_o = undamped natural frequency, rad per sec
ζ = damping ratio
K_E = error detector gradient, volts per rad
K_A = amplifier gain, volts per volt
K_T = motor torque gradient, dyne-cm per volt
K_F = motor damping coefficient, dyne-cm per rad per sec
J = total moment of inertia, gm-cm²
a = gear ratio, rad per rad

To increase the damping ratio, it is necessary to have low inertia J, high gear ratio a, and low gain $K_T K_A K_E$.

The quantity J is the total reflected moment of inertia of the motor, gear train, and load, measured at the motor. In instrument servos this can be closely approximated by the moment of inertia of the motor itself, plus possibly the inertia of the first gear. Therefore J is fixed when the motor is selected, and is independent of gear ratio.

If there are no dynamic accuracy specifications in an instrument servo, the gear ratio depends solely on the required following speed. For example, if motor maximum speed is N_M, and the load (say a pointer) is to turn at speeds up to N_L, the gear ratio may be as large as

$$a \gtrless \frac{\gamma N_M}{N_L} \tag{6}$$

where γ is a safety factor used to compensate for friction loading. The maximum no-load speed of the motor is N_M, but its maximum speed when used in a servo is reduced to γN_M. In an instrument servo, γ varies between 0.5 and 0.8.

The gain function $K_T K_A K_E$ is determined by the allowable static error ϵ_s. There must be at least

enough gain to overcome the friction load of the motor, gearing, and output devices, and the cogging of the motor. The reflected friction of the output devices at the motor shaft depends on the gear ratio. Often this contribution is quite small, so that all friction is assumed to be contributed by the motor, and is independent of gear ratio. The required gain function is then

$$K_T K_A K_E \gtrless \frac{T_{FM}}{e_s} \qquad (7)$$

where T_{FM} is the motor friction. Usually the motor manufacturer does not specify T_{FM}, but supplies instead the value of the control-field starting voltage, V_S, which includes all starting effects, such as bearing friction and cogging, and is therefore more accurate than the value of bearing friction alone. The expression for the gain function then becomes

$$K_T K_A K_E \gtrless \frac{K_T V_S}{e_s} \qquad (8)$$

In practice, the gearing and output always supply

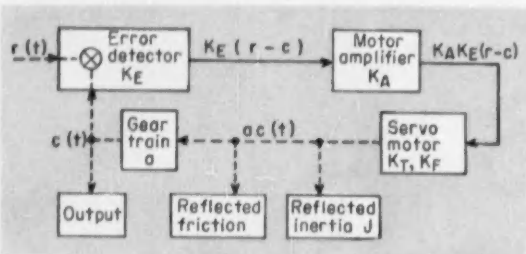

FIG. 3. Diagram of a servo using internal motor damping.

some frictional loading, so that a more correct expression for the gain function is

$$K_T K_A K_E \gtrless \frac{K_T V_S + T_{FL}}{e_s} \qquad (9)$$

where T_{FL} is the reflected friction torque of the gear train and load, measured at the motor. The load torque is determined after the gear ratio is selected; the gearing friction can be readily estimated. In low-dynamic-accuracy instrument servos, T_{FL} ranges from $0.2K_T V_S$ to $0.7K_T V_S$. Equation 9 places a lower limit on the gain function $K_T K_A K_E$. The values of K_T and K_E are fixed when the motor and error detector are selected. Therefore, the equations can be readily solved for the amplifier gain K_A.

The inequality signs in Equation 6 through 9 indicate the permissible variation in gear ratio and amplifier gain. To maximize the damping ratio, the equality signs must be used. This gives the largest possible gear ratio and the smallest gain. If these values do not yield a sufficiently large damping ratio, then motor damping is not satisfactory and another stabilization method must be used.

The natural frequency of this type servo is sometimes important. There are cases where the servo must act as a low-pass filter, attenuating spurious high-frequency inputs (noise), and here an upper limit is placed on the allowable natural frequency. With gear ratio and gain determined by the maximum following speed and the static error, the only way to reduce the natural frequency is to increase the inertia, for example, by adding an inertia wheel. This, however, also reduces the damping ratio. In practice it has been found that internal motor damping is not sufficient for servos requiring a very low natural frequency.

Servo design

The design procedure for an indicator-type instrument servo of the type discussed above can be summarized in the following eight steps:

1. Draw the block diagrams and select the various components—the motor, error detector, and output devices.
2. Select the gear ratio, using Equation 6.
3. Compute or estimate the friction load of the gear train and output devices, reflected at the motor, T_{FL}. Compute the total friction load $(K_T V_S + T_{FL})$.
4. Compute the gain function, using Equation 9.
5. Compute the motor damping coefficient K_F, using Equation 3 if motor characteristics are not available.
6. Compute the servo damping ratio, using Equation 5, and compare it to the required value. There are three possibilities—
   a. Damping ratio is too low. Try another motor that has a higher damping coefficient. If there is no such motor, then motor damping is not sufficient. Redesign, using a different stabilization method.
   b. Damping ratio is too high. This can be cured by increasing the amplifier gain. Compute the new value of gain from Equation 5 and proceed to Step 7.
   c. Damping ratio is right. Everything in order, proceed to Step 7.
7. Compute the natural frequency, using Equation 4, and compare it with the required value. If it is too high, compute the required added inertia using Equation 4. Then return to Step 6 and recompute the damping ratio.
8. Compute the amplifier gain from the gain function $K_T K_A K_E$. Select an amplifier. This completes the design aspects peculiar to this servo.

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DESIGNING A TYPICAL SERVO

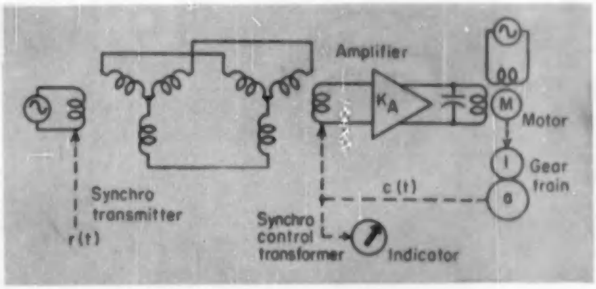


FIG. 4. Simple synchro servo for remotely positioning an indicator.

THE PROBLEM—Design a simple 400-cps synchro servo for positioning an indicator. The system specifications are:

Static accuracy	0.5 deg (0.00872 rad)
Velocity constant	none specified
Natural frequency	less than 10 cps
Slewing speed	greater than 3 rpm
Damping ratio	0.8 to 1.0

AND THE SOLUTION—Follow the eight design steps listed above.

1. DRAW DIAGRAM AND SELECT COMPONENTS–Figure 4 shows a typical indicator-type synchro servo with following components:

Motor–Kearfott Type R118

$$\begin{aligned} \text{rated voltage} &= 26 \text{ volts} \\ T_M &= 0.32 \text{ oz-in.} = 22{,}700 \text{ dyne-cm} \\ N_M &= 6{,}700 \text{ rpm} = 701 \text{ rad per sec} \\ N_S &= 8{,}000 \text{ rpm} = 836 \text{ rad per sec} \\ V_S &= 0.9 \text{ volts} \\ J &= 0.46 \text{ gm-cm}^2 \end{aligned}$$

Synchro–Dolecam Type 11CT4

$$\begin{aligned} K_E &= 1 \text{ volt per deg} = 57.3 \text{ volts per rad} \\ \text{inertia} &= 2.0 \text{ gm-cm}^2 \\ \text{friction} &= 0.5 \text{ oz-in.} = 3{,}550 \text{ dyne-cm} \end{aligned}$$

Output device–pointer with friction and inertia negligible compared to motor.

2. SELECT GEAR RATIO–Using Equation 6, assume γ equals 0.7.

$$a \cong \frac{\gamma N_M}{N_L} = \frac{0.7\ (6{,}700)}{3} = 1{,}562$$

$$\text{select } a = 1{,}500$$

3. COMPUTE TOTAL FRICTION LOAD–Determine motor torque gradient and total motor friction from motor specifications.

$$K_T = \frac{22{,}700}{26} = 873 \text{ dyne-cm per volt}$$

$$K_T V_S \cong 22{,}700\ (0.9) = 786 \text{ dyne-cm}$$

Compute synchro friction load reflected at motor shaft, and then introduce a factor of safety of 1.2 to cover estimated gear train friction.

$$\text{synchro friction load} = \frac{3{,}550}{1{,}500} = 2.37 \text{ dyne-cm}$$

$$(K_T V_S + T_{FL}) = 1.2(786 + 2) = 946 \text{ dyne-cm}$$

4. COMPUTE GAIN FUNCTION–Substitute the static accuracy specification and the total friction (from Step 3) in Equation 9.

$$K_T K_A K_E \cong \frac{K_T V_S + T_{FL}}{\epsilon_o} = \frac{946}{0.00872}$$

$$= 108{,}500 \text{ dyne-cm per rad}$$

5. COMPUTE MOTOR DAMPING COEFFICIENT–Substitute motor stall torque and synchronous speed in Equation 3.

$$K_F = \frac{1}{2}\ \frac{T_M}{N_S} = \frac{1}{2}\ \frac{22{,}700}{836}$$

$$= 13.58 \text{ dyne-cm per rad per sec}$$

6. COMPUTE SERVO DAMPING RATIO–Use Equation 5. Include a 20-percent safety factor in the inertia term to account for the inertia of the first mesh.

$$J = 1.2\ (0.46) = 0.55 \text{ gm-cm}^2$$

$$\zeta = \frac{K_F}{2} \sqrt{\frac{a}{J K_T K_A K_E}} = \frac{13.58}{2} \sqrt{\frac{1{,}500}{0.55(108{,}500)}}$$

$$\zeta = 1.18$$

This is close enough to the specification. Raising the gain 40 percent will lower the damping ratio to unity.

7. COMPUTE NATURAL FREQUENCY–Use Equation 4. Check to see if natural frequency is within limits.

$$\omega_o = \sqrt{\frac{K_T K_A K_E}{Ja}} = \sqrt{\frac{108{,}500}{(0.55)\ 1{,}500}} = 36.2 \text{ rad per}$$

$$\omega_0 = 36.2 \text{ rad per sec} = 5.76 \text{ cps}$$

With the gain increased 40 percent, the natural frequency will be 6.8 cps, which is still below the required maximum.

8. COMPUTE AMPLIFIER GAIN–Knowing the gain function, and the values of K_E and K_T, calculate K_A.

$$K_A = \frac{108{,}500}{873\ (57.3)} = 2.16$$

Increasing this 40 percent, the required closed-loop amplifier voltage gain is 3. If an amplifier feedback ratio of 10:1 is used, then an open-loop voltage gain of 30 is required. Note that the extremely low amplifier gain results from large gear ratio, low voltage motor, and high-voltage synchro.

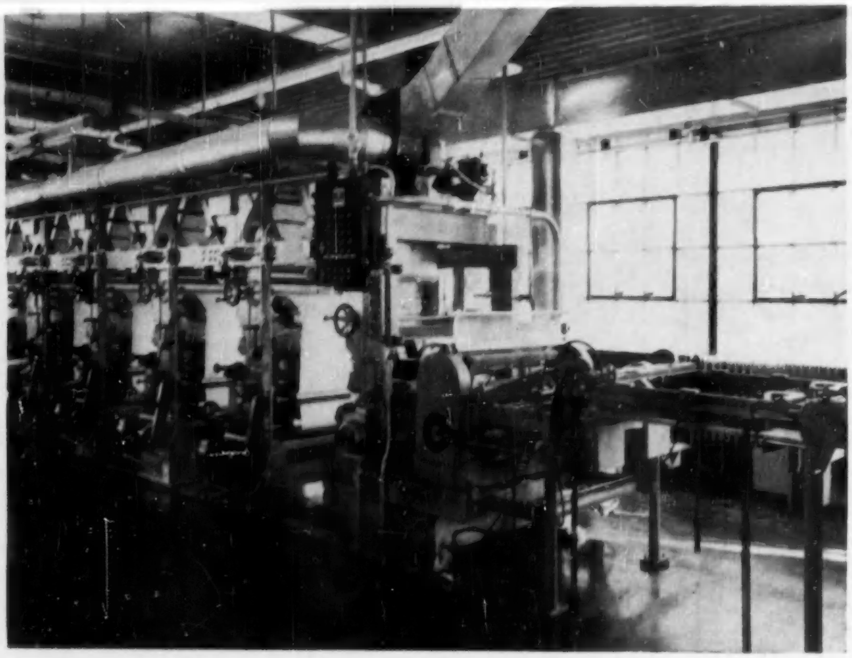


FIG. 1. The multi-color printing press is a major beneficiary of automatic registration control. As the paper web travels through the press from one printing station to the next, it picks up the separate color components of the design to be printed. The final result is a multi-colored design on the web that conforms with the original art-work. Automatic registration control assures that each part of the design is printed in exact correspondence with the other parts.

Controlling Register Automatically . . .

IMPROVES PRODUCT QUALITY AND REDUCES WASTE

JOSEPH C. FROMMER, Electronics Consultant

THE GIST: Automatic registration, wherein parts or designs are placed in exact correspondence with each other, is an important operation in making or converting many industrial products. Once the extent of registration quality has been decided on, the method of controlling the process is determined by the process itself to meet these performance requirements. Thus, where small deviations of short duration are expected, acceptable control may be effected by consecutive incremental movements of the controlling mechanism until the error returns to some value close to zero.

However, a fast process subject to large disturbances and random variations may require a more sophisticated control to attain product quality with a minimum of waste. An example of this type of control, as explained in detail in the article, is the combination of integrating action with proportional control and dead zone.

Using a multi-color printing press as a typical process, the article shows how the vagaries of the printing press determine which of the many available control modes will satisfy product quality specifications. Although concerned with registration of printed matter, the discussion will be useful in an investigation of any automatic registration control problem because of the similarity of concepts.

Automatic registration control is necessary in a large number of industrial processes, among which are converting of paper, film, and metal foil. Such industries require correct registration of one process with another, or registration of several operations within one process. Typical examples of automatic registration are stamping and punching of continuous stock and multiple-color printing on paper and cloth.

The equipment needed to provide automatic control, the type of sensing equipment needed for registration detection, the control technique that gives minimum waste product, and the method of imparting correction to the process depends on the required accuracy of registration, the material being processed, web speed, and the inherent characteristics of the processing machinery.

Automatic register of color components in a multi-color printing press

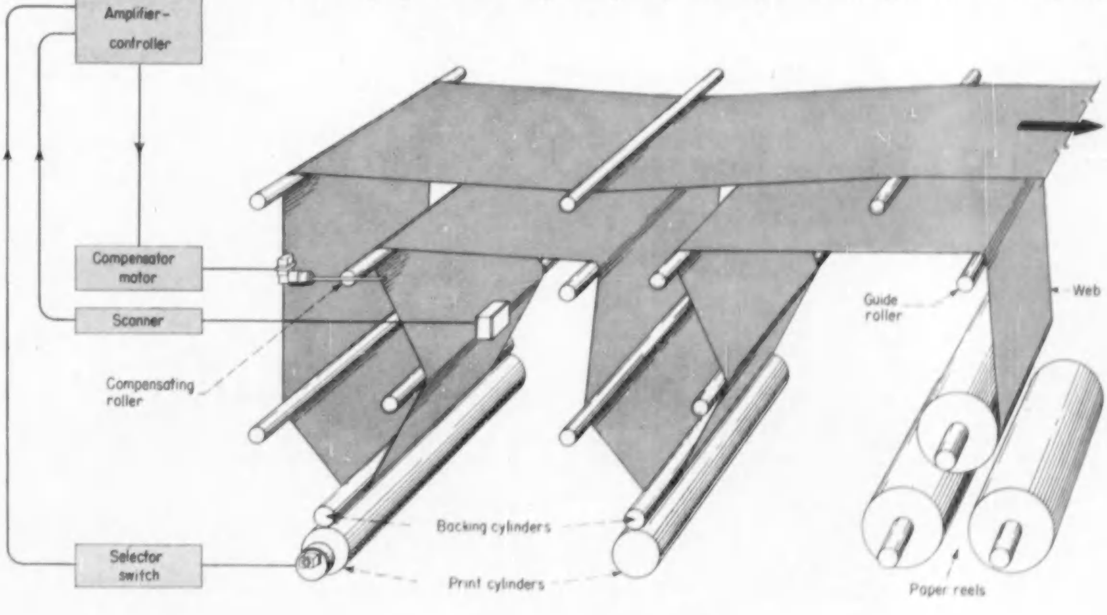
The multi-color gravure printing press is one of the many industrial machines needing automatic registration control. The different colors in an illustration must be printed in exactly the right place to reproduce the artist's ideas, to present information clearly, and to obtain esthetic quality. Any excessive deviation from the desired locations of the various colors destroys the value of the product.

Figure 1 illustrates a large printing press, and Figure 2 shows the schematic representation of two printing stations on the press. A continuous web of paper is fed from paper reels over guide rollers from one printing station to the other. At each station the web passes between the low printing cylinder and the upper backing cylinder. The printing cylinder is engraved with that part of the pattern to be printed in a certain color and revolves in a fountain of ink that color. The backing cylinder exerts the necessary pressure to transfer the ink from the printing cylinder to the paper to the web.

The principle factor in perfect registration is web length between adjacent stations. During running the web is subject to slight deviations in length, which can be caused by changes in ambient temperature, humidity, tension, quality of paper, and so forth. Usually these deviations are of the order of several thousandths of an inch. Larger errors occur at the end of the reel, when, without stopping the press, a new reel is moved into position and brought up to the speed. At the appropriate moment an automatic splicer cuts the expiring reel and splices the new reel to the end of the old reel. During this splicing operation serious variations in tension change the web length, and therefore spoil the register by several thirty-seconds of an inch.

Figure 3A is an example of acceptable register, while Figure 3B is an exaggeration of the type of mis-

FIG. 2. As the web passes the printing stations, it receives impressions in different colors. Since color register depends on maintenance of the exact web length between stations, variations in the web length due to such variables as humidity and tension cause misregister of the colors. The selector switch delivers a reference signal in a certain angular position of the printing cylinder, while the scanner generates its signal when the mark printed by the first color passes an illuminated spot. The amplifier-controller compares arrival time of the two signals and sends a correcting signal to the compensating roller to change the web length and restore register.



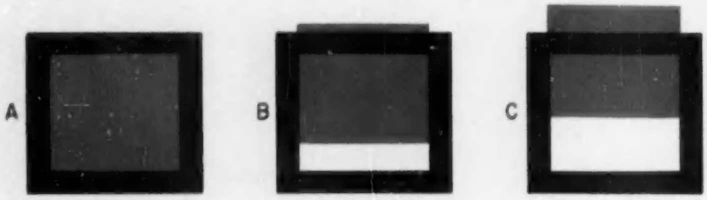


FIG. 3. This illustration typifies progressively poor register. Perfect register would center the colored square in the black border, as shown in A. During normal running slight misregisters (B) occur and may result in waste. A more serious case occurs when one reel of paper is spliced to another. This case, the result of a severe change in tension, is shown in C. All misregisters have been exaggerated for purposes of illustration.

register that occurs during normal press runs due to changes in tension, humidity, temperature, and other effects. The most drastic misregister, shown in Figure 3C, occurs during the splicing operation. Here the deviation extends to several thirty-seconds of an inch, and depending on the control system, results in some quantity of unacceptable printing that must be scrapped.

Both large and small deviations must be corrected by adjustment of the web length, accomplished by moving the compensating roller in accordance with the magnitude and direction of the error.

Detecting registration errors

When the web passes through the first printing station it receives, in addition to the first color, a mark which is sensed by a scanner (Figure 4) located on the second printing station. A phototube inside the scanner observes an optically-defined portion of a small illuminated area of the web and generates a signal when the scanner sees the edge of the mark.

Another signal, set off each time the print cylinder reaches a certain angular position, is generated by a selector switch coupled to the first cylinder. The angular position is chosen so that when the printing is in accurate register the signals generated by the scanner and the selector switch occur at the same time. When misregistration occurs the scanner signal leads or lags the switch signal, depending on the direction of the deviation.

Thus, the registration detector (the detecting arrangement just described) delivers a signal indicating the magnitude and direction of the error to a controller. The controller then sends a correction signal to the motor driving the compensating roller. There are a number of ways for the controller to compute the corrective action required and there are also several ways to impart that correction to the compensating roller.

A review of control and correction

Four methods achieve registration control of printing presses, and these can be applied to other registration control problems in other areas of industry. The control modes, similar to those used in flow process control, are reviewed here briefly.

▶ Fixed Increment Control—calls for correction in one direction, in the other direction, or not at all. It initiates a correction of a certain amount, say 0.005 in., irrespective of the magnitude of the misregister reported by the scanner and selector switch. Fixed increment control is the simplest system.

▶ Proportional Control—makes the correction dependent not only on the direction of the deviation, but also on its magnitude. Thus, corrections for large misregistrations will be greater than for small.

▶ Proportional Plus Rate Control—computes the rate of change of consecutive error signals, anticipating increasing or decreasing misregister, and delivering signals that correct for error magnitude and rate.

▶ Integrating Control—computes a correcting signal depending on the integral of the error signal curve. This mode, combined with proportional control and a dead zone, appears to be the most suitable (of those mentioned) for printing press registration control, and will be discussed in greater detail later.

Once the computer has established the amount of correction needed by the compensating rollers there are several ways to impart that correction. For fixed increment control a constant-speed motor driving the compensating roller runs continuously (but only for a certain length of time) upon receiving a correction signal. When another error signal is received the compensating roller moves another small increment. Correction continues in this way until no more is needed, or until the system calls for correction in the opposite direction. The time duration of the drive signal can be tied to the speed of the press so that if press speed varies the amount of correction imparted for each signal remains the same.

All the control modes mentioned above, with the exception of fixed increment control, require variable-magnitude correction as computed by the controller. Variable correction can be obtained either by varying the speed of the drive, or by keeping the motor speed constant and changing the time duration of pulses and the intervals between them, depending on the size of the required correction.

AN EVALUATION OF CONTROL MODES FOR AUTOMATIC REGISTRATION CONTROL

The table, "How Register Responds to Control", illustrates the types of response that can be obtained with no registration control and with the four control modes described above. The time axis (or, equivalently, the number of copies printed) represents about 50 cylinder revolutions. The left portion of this curve illustrates normal running, while the right

portion shows the large deviation that occurs during the splicing operation. The vertical axis represents register deviation, the middle line perfect register, the outside lines represent the acceptable limits of register, and the intermediate lines the limits of the dead zone.

The table contains, in addition to these graphs of register control, a brief interpretation of the results of the various control modes. The following evaluation of these methods brings out the salient characteristics of the printing press on which depends the selection of a suitable register control.

The simplest mode of all is fixed increment compensation, but it has one serious limitation: if a large misregistration occurs, as during a splicing period, each correcting impulse corrects only a small fraction of the total error. Thus, it takes a large number of incremental corrections to restore exact register. The magnitude of incremental correction which determines the system solution must be maintained smaller than allowable register tolerance. Otherwise, larger corrections might overshoot the acceptable region. Despite the fact that a large error requires a long correction time, fixed increment register control, with a correction in the order of 0.005 in. per increment, has been used extensively for many years in a great number of printing plants.

The ever-increasing desire for improvement in quality of register and for decrease in waste during splicing has made it imperative to reduce the minimum amount of correction imparted and at the same time to increase speed of correction during periods of fast changes in register. Proportional control meets these dual requirements, because it allows fast correction when large deviations of register occur, yet corrects to as fine a resolution as desired during normal press operation.

Rate control, which results in faster correction, uses a prediction of future deviations obtained from the observed past deviations. The amplifier-controller can be so designed that if the detected deviation increases with successive scanning periods, a larger correcting movement is initiated to anticipate an even larger deviation in the following period. And inversely, if the detected deviation decreases, less or no correction is imparted, on the assumption that the printing press has a tendency to correct this deviation by a spontaneous shift in the proper direction. This assumption, however, has the following weakness: predictions of future misregister are valid only to the extent that the possible changes of rate of change (second derivative of curve obtained by plotting the consecutive error signals) are known.

If this second derivative were completely understood, future errors could be predicted from magnitudes and changes of earlier deviations. In some processes this second derivative is governed by immutable laws of nature, in other processes designs and dimensions limit the second derivative (or some higher derivatives) to within some close range of values. Neither of these limitations can be used to predict deviations of printing presses, for factors such as quality of paper, type of printing, speed of press, paper tension, and so forth, create so many variables that it is difficult to predict how close future changes will follow the trend of earlier changes. Plots of register deviation during splicing under varying conditions show such considerable variations in the second derivative of misregistration error that, while rate control may prove highly useful in certain processes, it seems to hold little promise for registration control in the printing field.

Past information is not, however, without value in the field. As the demand for better registration drove the resolution to closer and closer limits, it turned out that vibration of the printing press frame caused errors in the exact indication of register. Although the overall rms value of these errors is in the order of 0.001 in., peaks often reach 0.005 in. and more.

As long as the system uses fixed increment control even these peak errors are of little importance. This type of control includes a dead zone (around the point of perfect registration) of two or three thousandths of an inch, which prevents any slight errors from causing an unwanted correction. Thus *effective* dead zone (deviations of register not corrected for) is the actual dead zone minus the peak values of frame vibration errors.

Proportional control theoretically requires no dead zone, but practically it does require it, for without it the system would continuously correct for frame vibrations and other small errors. As a means of overcoming correction from these spurious signals, a dead zone could be considered. The dead zone would be just wide enough to accommodate normal errors added to the indication or perfect register, so that

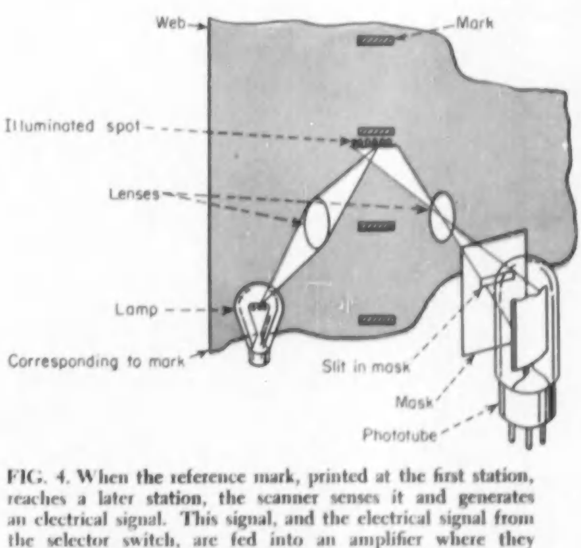
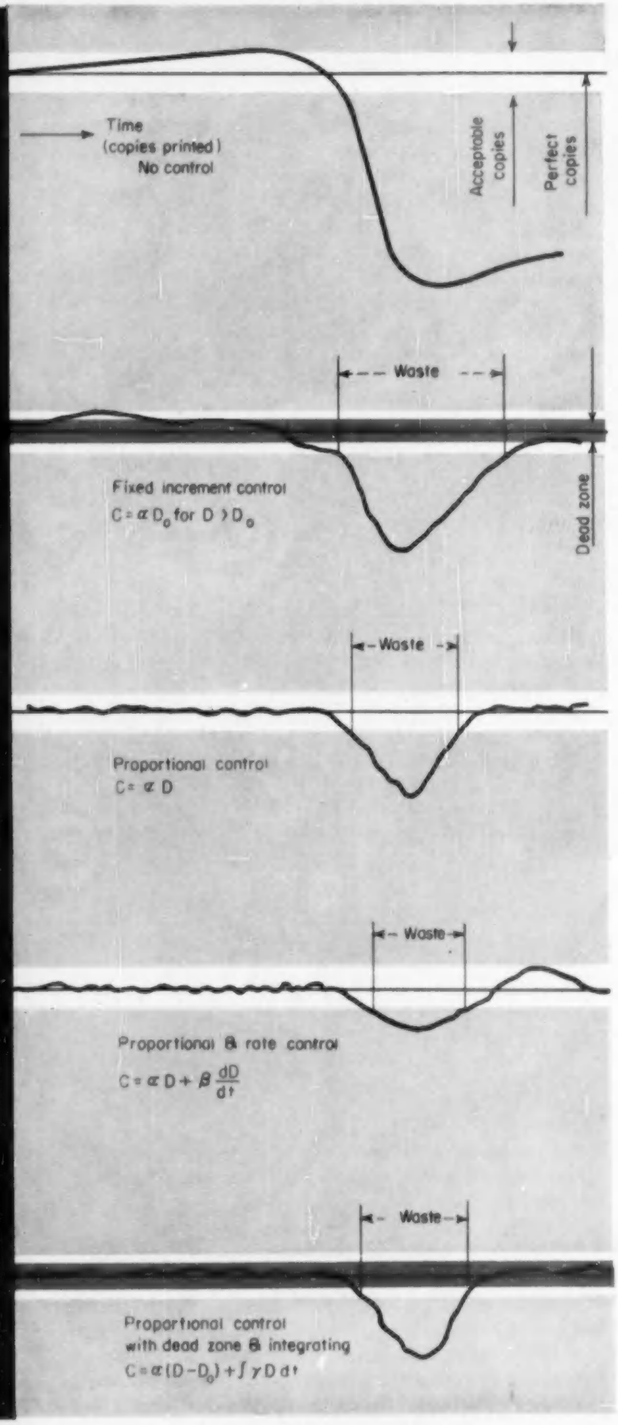


FIG. 4. When the reference mark, printed at the first station, reaches a later station, the scanner senses it and generates an electrical signal. This signal, and the electrical signal from the selector switch, are fed into an amplifier where they undergo computing determined by the control mode selected.

HOW REGISTER RESPONDS TO CONTROL

C = Correction; D = Deviation; D_0 = ½ Dead Zone

α, β, and γ are factors effecting stable control



Without any register control on the printing press the register drifts outside of limits during normal running and suffers large deviations as a result of splicing a new reel to the expiring one, and there is no assurance that acceptable register will be restored. Copy printed outside of acceptable limits must be scrapped. Deviations resulting from splicing is shown at the right of the graph.

When the printing register is controlled by the fixed increment mode the register is maintained within acceptable limits during normal running, as shown at the left. Following splicing, however, (while the control incrementally corrects the deviation) a certain amount of waste occurs. Finally, register returns to within acceptable limits, as shown at the right.

With proportional control, waste is further reduced. Although the random activity of the scanner causes corresponding small random deviations in register, the running register is improved.

When rate control is added to proportional control, the corrections occur faster. However, overcorrections come about because of the possible erroneous anticipatory effect of the rate action, and there is a tendency for over-emphasis of random corrections.

Combining integrating action with proportional control results in response similar to that obtained with proportional control during the splicing period, for here the proportional mode is predominant. However, control is closer in normal running because the integrating mode adds up consecutively sampled small deviations and effects a correction for the slightest deviation from the desired average. This latter control mode also minimizes random corrections during normal printing runs.

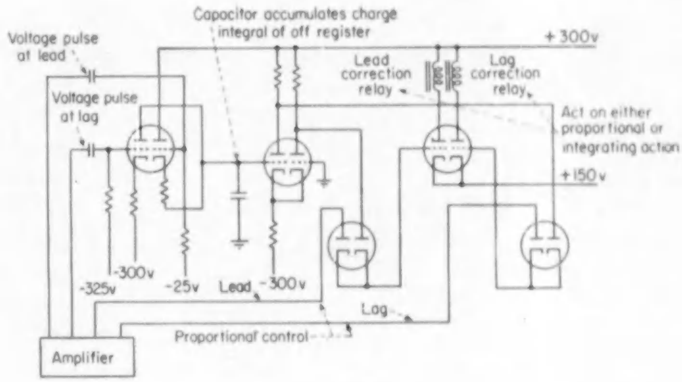


FIG. 5. Because the register detector puts out electrical signals the necessary amplification and computing can be accomplished electrically. The circuit shown here, and explained in the text, corrects for accumulative small deviations through its integrating action and corrects for larger deviations through its proportional action. Either type of misregister operates one or the other of the correcting relays to move the compensating roller and thus change the web length and re-establish perfect register.

any deviation from perfect register outside the limits of the dead zone would call for correction. The principle of adding dead zone to proportional control works fine in processes where the magnitude and distribution of random error signals remain constant. But this is not always so with printing presses.

In printing presses random vibrations come from a number of sources having different periods, and their repetition, therefore, is extremely irregular. However, the vibrations have this one reliable and immutable characteristic, a result of the fact that they are caused by the linear interaction of elastic vibrations: their average value is strictly zero. Therefore, the sum of consecutively sampled errors with perfect register yields a zero value, but the summed error will invariably grow one way or the other if register deviates by the least amount. Whenever the summation (or integration) of the errors indicates misregister one way or the other a small correcting pulse, equal in magnitude to the desired resolution, can be applied to the compensating roller. Thus, a dead zone can be set to ignore even the maximum random error, and register can still be held at the optimum consistent with the actual printing press.

Error signals may be integrated in many ways, depending on the transmission medium of the signals. In the case of electrical signals, which come from the photoelectric scanner, the integration can be performed electrically. An electronic integrator (Figure 5), developed (pat. pending) for Electric Eye Equipment Co.'s Hurletron Type 96 circumferential registration control system, has the characteristics needed to achieve improved registration in multi-color printing. This arrangement, which includes proportional control and dead zone, is one way of obtaining an industrially acceptable registration control. It will be discussed in the following section. The principles mentioned, applicable to other areas of automatic registration control, should indicate analogous ways of devising similar controls.

HOW INTEGRATING ACTION IMPROVES MULTI-COLOR REGISTRATION

Figure 5 illustrates the basic circuit for obtaining integration of error signals, and includes the aforementioned proportional control and dead zone for ideal control. Essentially, this circuit contains two similar paths for error signals, one for lead deviations and one for lag deviations. An error in either direction operates the appropriate correction relay to drive the compensating roller in the proper direction and thus diminish the registration deviation.

The amplifier associated with this circuit has two sets of outputs, one set delivering signals proportional to the magnitude of large deviations, and the other set delivering signals proportional to small and random errors. Proportional lead and lag signals proceed through their associated diodes, connect to the grid of a triode, and operate one or the other of the correction relays in the output of the triode. Closed contacts on a relay energize the compensating motor.

The integration of small error signals is accomplished by sending into a capacitor a charge that is positive or negative depending on the direction of the deviation, and that is proportional to the magnitude of the deviation. If the average of all errors is zero, the voltage on the capacitor stays unchanged: the positive charges increase capacitor voltage exactly as much as negative voltage decreases it.

If the average is not zero, the capacitor voltage will increase in one direction. This integrated voltage, applied to a grid of the second twin-triode, changes the voltage drop across one plate resistance. This signal eventually reaches one of the grids of the output tube which drives either correcting relay.

Neither relay, however, will operate as a result of a small error until the voltage across the capacitor exceeds a high or low limit equivalent to the dead zone. This limit is established by biasing the tubes. Once the dead zone is reached (through an accumulation of excessive random vibration errors, slight deviations in register, or signals proportional to the magnitude of large deviations) the correcting relay operates to drive the compensating roller to minimize the misregister.

Even a small deviation (if it persists long enough) will be integrated by the capacitor and develop a correcting signal. The capacitance can be chosen to have correction occur as fast as is consistent with the pattern of random errors present in the particular printing press being controlled.

Controlling A Process

THE GIST: The first eight articles in this series dealt with the use of digital computers for solving scientific problems and for processing business data. In these applications, computing speed did not affect system operation, and, in general, the output did not modify the input. Now, with this article, the series turns to the use of digital techniques for real-time process control. These techniques share with analog techniques the advantages of economic process optimization and direct control of end quality; but only digital techniques offer high accuracy and flexibility inherent in a stored-program machine.

Although new, digital control techniques have made successful inroads in several areas. Airborne computers for navigation and weapons control have proven successful. Many numerical information-processing systems for the control of machine tools and other production processes are beginning to find their way to the factory floor. Systems for air-traffic control, real-time simulation, automatic component testing, and automatic assembly are in various stages of development.

Despite this record, engineers have been slow in applying digital techniques to control system applications. Two reasons are: one, slim understanding of the interaction between system and digital computer; and two, the difficult input-output problem. In science and business, the inputs and outputs are numerical by nature—coded and printed numbers or characters—but control starts and ends with physical quantities. Matching these quantities to a numerical control computer is generally unnatural.

Dr. Salzer discusses the basic principles of digital control and concludes with a comprehensive list of references. Succeeding articles will cover sampled-data techniques, encoding and decoding, digital control system design, and telemetering.

JOHN M. SALZER
Magnavox Research Laboratories

To understand the application of digital techniques to control, some of the important characteristics of digital elements[1] must be known. A number is a *weighted representation* of a physical quantity, each digit position having a different weight attached to it. In the decimal notation the weights are powers of 10, in the binary notation powers of 2. Using an identical physical element for each digit of the number is basically an expensive way of representing a quantity (a different element for each complete number would be cheaper), but is justified by simplifications. *Quantization* yields one simplification. Each digit in the weighted representation is required to distinguish only a fixed number of states: ten in the decimal case, two in the binary case. Note that weighted representation does not inherently require the quantization of each digit, as is shown by the well-known use of continuous (nonquantized) coarse and fine dials. Since two-state elements are most easily realizable, digital controls use a binary-type number system.

Efficient techniques are available for storing binary digits, but their manipulations—such as addition, or multiplication by a constant—require an excessive amount of equipment. For this reason it is generally not practical to provide as many adding units as there are additions to be performed in a control application. A saving is achieved by time-sharing the computing unit, but this immediately necessitates the *sampling* of data. Information does not pass through the digital computer continuously; rather the values of quantities are noted at specific times and computations are carried out in sequence (one operation after the other) until a result is obtained. Then the next set of samples can be accepted for computation.

An important advantage of digital mechanization is the computational *precision* that can be attained. Accuracy can be doubled for the relatively low price of a binary digit, and thus is inherently limitless. This is important in certain control problems. Note the rapid advances in the digital control of precision machine tools and certain military weapons. The refinement attainable through digital techniques should improve the control of various industrial processes[2].

Another possible advantage of a digital computer is its *flexibility*: the proper coded information can make the computer perform a new control function. Insertion of this information can be automatic by means of punched cards, magnetic tape, or similar input media. Although this feature is obtained at the price of simplicity—considerable circuitry capable of automatically interpreting the coded program is needed—such an interpreter is much simpler in a high-speed digital computer than in

an electronic analog computer, where accurately switching continuous voltage levels is difficult.

While flexibility is desirable, its usefulness in control applications is often overemphasized. It is most valuable during the development phase of a system, when it is desirable to try out various solutions on the same computer, although it is useful in several other areas too. Among them: physical simulation, a field in which digital computers are just beginning to prove themselves[3] (here short setup time is particularly important); variable-program computers, which are useful in so-called supervisory control applications (where the computer is used mainly as a decision maker); and automatic testing of components, automatic assembly of electronic circuits, or the automatic machining of complex workpieces from recorded information, where flexibility through different programs may make it economically feasible to automatically test or manufacturer limited numbers of units.

Related to their flexibility is the ease with which digital computers can perform *nonlinear* operations. Decision making is really a nonlinear operation because it is based on comparisons, or on the solution of equalities and inequalities. Multiplication, division, and other nonlinear operations can be most accurately mechanized digitally. Consider, for example, air or ground traffic control by a central computer. The operations to be performed include counting, sorting, and solutions of nonlinear functions of speed, time of day, road conditions, etc.

Another feature of digital equipment is its *memory*, which can be as reliable and nondecaying as it is able to forget completely, depending on what the programmed instructions say. In this way closed-loop systems can be compensated to have a fixed length of time for their transient response, rather than a gradually decreasing transient[4]. In systems having long time constants, such as chemical or petroleum processes, storage, an essential requirement, cannot be satisfied otherwise except by mechanical or manual means. Low-frequency drift and the subsequent need for recalibration are not encountered with digitally stored quantities.

To take advantage of these features inherent in digital techniques, the designer must establish suitable links between the computer and the rest of the system. This is the conversion problem.

How the computer communicates with the system

The root of the conversion problem rests in the basic nature of control, which is to measure physical quantities and control physical units. This is "instrumentation", which covers both the low-power measuring elements and the high-power actuating elements. Past instrument design efforts were directed toward matching the type of monitoring and servo systems that were prevalent. Whether the physical quantity was pressure, range, velocity, torque, or even frequency, the instrument designers attempted to produce a shaft position or voltage signal for feeding an analog control system.

The advent of digital controls found the instrumentation industry substantially unprepared as far as radically new instruments were concerned. Thus, the tendency was, and to a certain extent still is, to accept existing instruments and provide conversion devices between shaft positions or voltage levels on one side, and digital representations on the other. Many of the commercially available shaft digitizers and voltage-digital converters will be covered in a future article in this series.

Today, however, efforts are being made to attack the digital instrumentation problem on a more fundamental level. Direct digital position measurements for machine-tool control can now be accomplished by photoelectric, electrostatic, magnetic, and mechanical means[5,6]. And, as with the shaft digitizers, there are two basic methods of measurement: absolute and incremental. In an absolute measurement a complete digital code is generated at each position, and no reference need be made to previous measurements. In an incremental measurement only incremental or quantized changes are noted, and the absolute measure of position is determined by accumulating all past increments. A third method of measurement is also in use: here a pulse or cycle repetition rate proportional to measured quantity is produced. As will be seen, digital processors can be designed to match any of the types of measurements.

Time and frequency measurements are fundamentally compatible with digital computer techniques. Pulsed radar range is measured as a *time interval*, and a digital indication can be obtained by counting into this time interval at a constant known pulse rate, Figure 1. Accumulated counts over a fixed number of echoes can produce an averaged or smoothed digital indication of range. Straightforward as this sounds, in many applications it is still simpler to use existing radar sets and convert from the available shaft or voltage indication of range. With continuous radar, an incremental indication can be obtained every time there is an additional cycle of delay in the reflected wave. The primary measurement of time differences was exploited in a hyperbolic navigation system[7], and can be considered in the measurement of speed or volumetric flow.

A *frequency* is readily converted to a proportional numerical value by counting over a fixed time interval, Figure 2. A digital pressure transducer manufactured by the Byron Jackson Electronics Div. uses a stretched wire that vibrates at a frequency determined by pressure. A Fischer & Porter ultrasonic flow meter measures flow

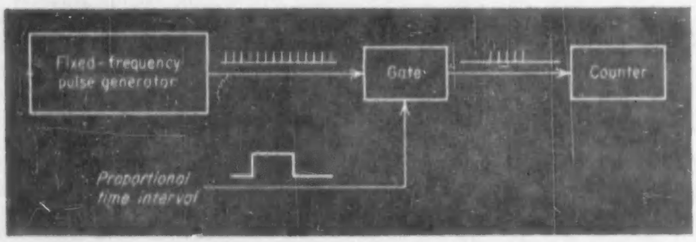


FIG. 1. Time-to-digital conversion.

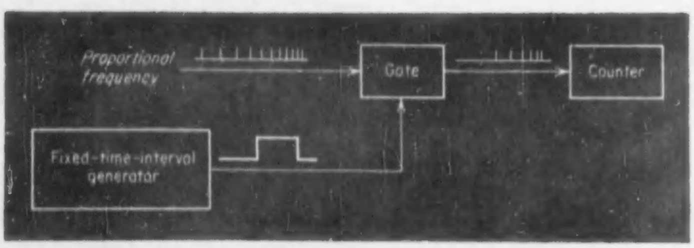


FIG. 2. Frequency-to-digital conversion.

by the difference in pulse rates upstream and downstream. Doppler radar produces a beat frequency directly proportional to the rate of change of range. Signals are often telemetered in frequency-modulated form, and their direct utilization in pulse-rate type computers has been considered[9]. In manufacturing process control, pulse rates can often be derived directly from "benchmarks" on a moving object.

When information is available in digital form, such as in pulse code modulated transmission links, it seems natural to use a digital processor. However, the designer should be wary of jumping to conclusions. The available digital data may be incompatible with the digital computer in pulse rate, synchronization, or code to such an extent that the digital-to-digital conversion called for might actually be wholly impractical. The author knows of one case in which a combination of digital-to-analog and analog-to-digital conversions appeared more practical than a "straight" digital-to-digital conversion. As always, catalogued solutions are no substitute for sound engineering.

In the output to the actuating element there are the problems of conversion, storage or interpolation, and power generation. Some provision must be made to present the output samples to the controlled equipment as continuous data. The simplest means of extrapolation is to clamp the last sample until a new one is computed, Figure 3. If the clamping or storing is done digitally, a separate converter is required for each output quantity. For economy, the converter is usually time-shared between several outputs (and inputs[8]) and the information is stored in the analog form. To clamp a voltage and support the load a cathode follower or similar circuitry may be required. A slight revision of this circuitry can provide a higher order extrapolation than clamping[10].

A servo system is required if the analog output quantity is to be represented as a shaft position. The technique of converting to a voltage first and then servoing the shaft to this voltage is becoming outmoded, Figure 4A. Some indication of shaft position now is being obtained in digital form and servoed directly against the digitally computed value, Figure 4B. Again the digital comparison may be either absolute or incremental, depending on whether the absolute value of shaft position or the incremental change in angular position is fed back to the error device. Because of the permanent offset caused by a lost increment, the absolute measure is often preferred. However, the incremental measure may be satisfactory if it is inside a broader closed loop that has zero steady-state error. A good match between incremental output from a digital computer and shaft position can be obtained by using a notching motor[11]. This technique is used to convert the output of certain machine-tool numerical directors where synchro follow-up systems are used.

The need for radically different devices at the point of actuation is somewhat less pressing than at the point of measurement. Actuators are expensive, so that only moderate gains could be obtained by adding elegance in conversion. Furthermore, when actuation is provided by a servomechanism, the same digitally compatible measuring instruments developed for the computer input could streamline the output. Some designs use a time interval (phase measure) or a frequency (pulse rate) for comparison in the output servo-system.

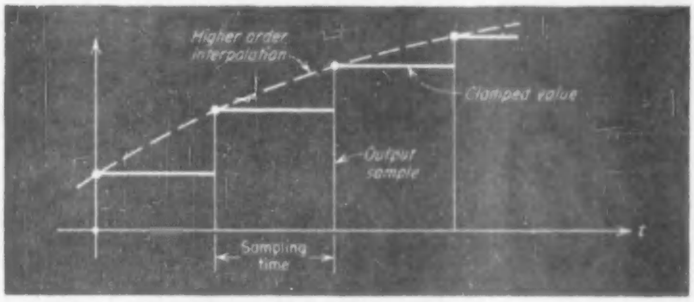


FIG. 3. Clamping the output sample.

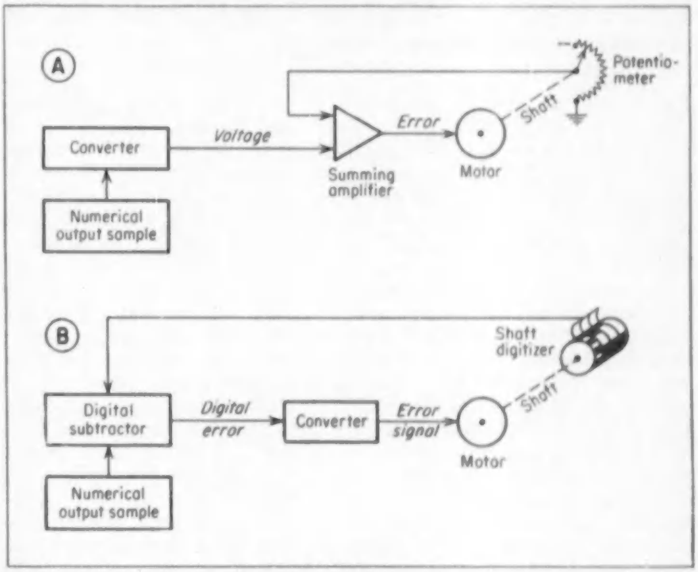


FIG. 4. Digital-to-shaft-position conversion: A by voltage comparison, B by digital comparison.

Controlling with an absolute computer

In a so-called absolute computer, each computational step uses the full values of the involved quantities, although in most control problems the various quantities change relatively little between computing cycles. Some control applications, however, require this technique.

Programmable absolute-type computers are usually called general-purpose computers in the literature. Given sufficient time, these computers can perform almost any computing task called for by the program. As pointed out in the previous articles in this series, computers of this kind have been developed to a high degree of reliability and are widely available. The designer should consider their use in a control system despite their drawbacks, since it is time consuming and expensive to develop a special-purpose computer. Sometimes, in fact, a programmable absolute computer is reasonably close to an optimum choice.

The choice and design of such

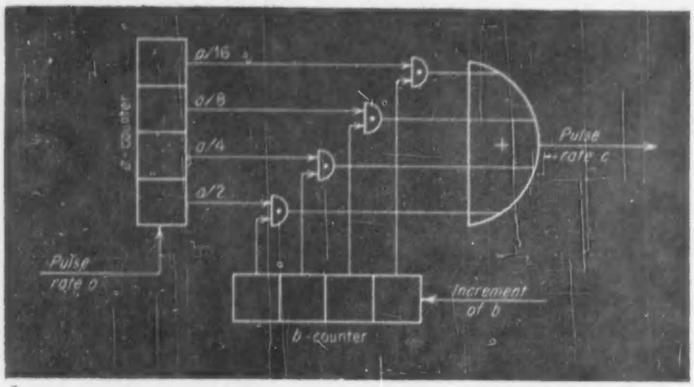


FIG. 5. Four-digit binary-rate multiplier.

a computer are circular procedures. One of the most critical parameters in control applications is the computing time—the length of the computing cycle. The designer must define the equations to be solved and estimate the number of program steps necessary to solve them. This, together with the operation times of the computer or type of computer under consideration, gives a first estimate of computing time. The designer can then determine the dynamic effect of the computer on the system. A practical rule of thumb is to replace the computer by an instantaneous computation in cascade with a pure delay of between one-and-one-half and two times the estimated computing time to account for the effects of sampling, input delay, computing delay, and output clamping. Means of analysis have been widely presented in the literature[4, 10, 18, 14]. Depending on dynamic effect, the designer may consider a slower and cheaper or a faster and more expensive computer on the second go-around of design procedure.

An absolute computer can be specialized by fixing its program[16], or by heavily restricting its instruction complement[16]. As yet, however, the resulting simplifications have not compensated for its disadvantages.

No matter what computer is chosen, the input-output equipment must be specially considered for each application—and this equipment can easily become more complex than the computer proper.

Controlling with an incremental computer

The first departure from general-purpose absolute computers was a development at Northrop Aircraft Co., announced in 1949. This was the first digital differential analyzer[17]; its basic operation is a simple numerical integration defined by

$$\Delta z = y\Delta x \qquad (1)$$

in which the incremental change in the integral z is calculated by multiplying the full value of the integrand y by the incremental change Δx in the variable of integration. The indicated muliplication is particularly simple if Δx is allowed to take on a limited number of values. In two-valued (named variously binary or dinary) incremental arithmetic, a plus one or minus one quantum is the only permissible value for Δx or Δz (an alternation of positive and negative quanta signifies a zero). In a three-valued (ternary) machine, 1, 0, and -1 are the permitted increments. In either case, the multiplication reduces to simple addition or subtraction.

In commercial computers of this type, the arithmetic unit consists simply of an adder-subtractor, and a magnetic drum provides properly arranged storage of the quantities to be used in each successive step of the calculation. Information coding on the drum gives considerable flexibility in sequencing this one (in some computers as many as four) operation with different combinations of variables. A typical application for such a computer is the numerical solution of differential equations. While this type of computer is specialized to a few types of operations, it is quite general in that it solves different problems according to coded instructions. Actually, a large variety of functions and operations can be synthesized from the basic step defined by Equation 1.

Incremental computers can be used in control applications if the variables change only a small portion of their full value from one computation cycle to the next. These computations take cognizance only of the changes in the variables, and make adjustments of the results accordingly. In the basic design of several such computers at the author's company, the problem of system integration consisted of finding the proper balance between sampling time, quantization, increment size, and noise filtering.

The accuracy requirement on each variable determines the quantum (or least significant bit) size. This in turn, together with the full values of each variable, determines the number of digits required to represent each variable. The bandwidth of the signal inputs multiplied by a factor of five to ten usually defines the minimum sampling or computation rate, provided that the higher noise frequencies in the inputs can be removed before sampling. A tentative computation time is chosen, and the maximum change of each variable per computation time interval determined. This change is the increment size for each variable that the computer must handle. Note that the increment size can be greater than one quantum size. With some type of mechanization in mind, the designer can now get a tentative computer configuration and compare its performance with system requirements. The final design is obtained by successive—and hopefully convergent—iterations of these design steps.

The first incremental computers used magnetic-drum storage; actually, though, any kind of storage can be considered. Depending on required speed and capacity, acoustic delay lines, coincident-current magnetic cores, or shifting magnetic cores can be used. The arithmetic may be serial or parallel, or a mixture of both. It is also possible to use more than one arithmetic unit. The variety of possibilities is quite large.

Controlling with a pulse-rate computer

In a pulse-rate computer, the variables are represented as either binary numbers stored statically, or as pulse rates. The latter representation requires a frequency or pulse rate proportional to the variable. Note that this differs from incremental representation, where an increment occurs only when the variable changes. In a pulse-rate computer, a pulse rate must be maintained even when the variable is not changing.

The pulse-rate computers discussed in the literature use a so-called binary-rate multiplier[18] as their basic building block. The four-digit binary-rate multiplier of Figure 5 is typical. Assume that *b* is a constant binary number with the binary point on the left, and that a pulse rate proportional to the variable a is applied. The *a*-counter is used as a four-fold frequency divider, so that its output pulse rates are proportional to a/2, a/4, a/8, and a/16. The AND gates controlled by the *b*-register allow the

proper rate to pass to the c-rate output. If b is ½, or binary .1000, the output rate c will be a/2. In general, c is the sum of up to four of the pulse rates of the a-counter. Pulse-rate overlapping can be avoided by tapping the flips, rather than the flops, of the a-counter flip-flops.

The average pulse rate at the output of the binary-rate multiplier represents the product ab. The c-rate is properly averaged if the averaging time is an integer multiple of the full-count time of the a-counter, and if it can be assumed that b stays essentially unchanged for this time. The dynamic limitations of this kind of arithmetic device are apparent: consider that in a control problem both a and b could be variables, and that for greater accuracy more digits per counter are required. Often many such rate multipliers must be cascaded, and such operations as division must be performed by using rate multipliers in iterative feedback loops, further decreasing the dynamic effectiveness of the method. Depending on the problem, the basic pulse repetition rate of such a computer may have to be 10^{x} to 10^{x} times the required sampling (or computation) rate. These ratios are several orders of magnitude greater than those required in an incremental computer.

Pulse-rate computers can be used in low-bandwidth applications (1 to 2 cps), as in petroleum or chemical process control systems or component testing. Rate multipliers are readily constructed, and their proper interconnection leads to a relatively direct mechanization of computation. As noted previously, in some cases this type of computer is readily compatible with the form of input data.

What the future holds

It is not bold to predict that the use of digital techniques in control applications will rise, but to say how fast or how far is more difficult. The greatest boost may come from the development of novel instruments, designed for compatibility with digital mechanization. In fact, without this the field of digital controls is strictly limited.

The second most important factor will be the greater concentration on developing special-purpose computers and computing techniques. As a fuller understanding of the theoretical and experimental aspects of control systems and digital techniques is attained, the solutions for special tasks will become more apparent.

The development of improved communication methods compatible with digital computing techniques is another area of fruitful concentration. And methods of system analysis and synthesis have recently been aimed at problems associated with hybrid system design. The point has been reached where the control engineer cannot disregard the potential of digital techniques in most problems.

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JOHN M. SALZER

A year after he received his bachelor's degree in electrical engineering from Case Institute, Dr. Salzer joined MIT's Project Whirlwind, which gave him valuable experience in applying digital computer techniques to automatic control systems. This was in 1948, the year which also saw him garner a master's degree in EE from the same institute. Three years later, in 1951, he joined Hughes Aircraft Co.'s airborne digital computer project, where he continued work on the mating of the digital and control fields. Also in that year he earned his doctorate in EE from MIT. In 1954 Dr. Salzer went to Magnavox Research Laboratories, where today as director of systems, he concerns himself with both control and data-processing problems.

A Trainer for Chemical Process Operators

J. P. LAIRD
E. I. du Pont de Nemours & Co., Inc.

This trainer is a static analog of the control room graphic panels for a new chemical plant. It proved most valuable in familiarizing future operators with the plant and its operating conditions before the plant was built, and resulted in less obvious gains, too.

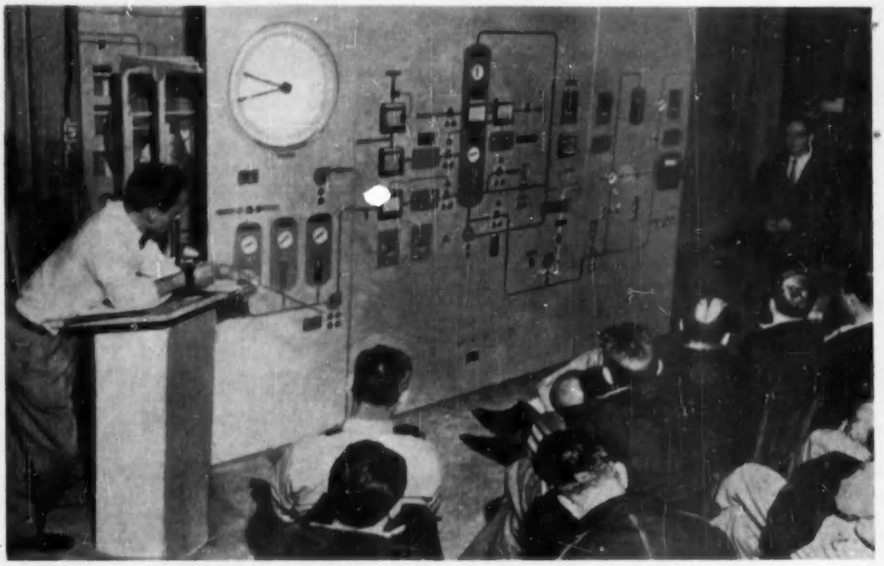

FIG. 1. Instructor points out feature of process on three-panel section of trainer. Power supply racks are behind panel.

The chemical industry is experiencing an increasing demand that new products be put into production quickly. One of the most difficult problems this poses in a new plant involves the training of plant operators. Usually these men are drawn from other types of work and must be trained to operate complex chemical manufacturing facilities from an elaborate central control room.

Recently du Pont attacked this problem along different lines, using a process trainer to simulate the entire central control room of a new plant. Operators learned about the plant and received on-the-job training while the plant was being built.

The success of this approach was outstanding in a number of respects. First, the information was conveyed to the student more quickly and more accurately, and stayed with him longer. Second, a checkup on what he learned was provided by letting him "operate" the plant. Third, he learned what to do in a large number of potential emergencies, thus subconsciously becoming familiar with the inner workings of the processes.

During World War II the Navy developed "synthetic training devices" to train men in most phases of warfare. The process trainer is based on these same techniques. Development of the trainer was a joint effort between du Pont as user and the Carmody Corp. of Buffalo, whose president, ex-Navy man Ed Carmody, has been active in training work since 1941.

The process trainer consists of a number of panel sections which in appearance duplicate the panels of the central control room of the plant. Over 100 ft of panel are simulated. Dummy instruments are mounted on the panels of the process trainer. In this case the instruments were actual front portions of indicators, recorders, and other control room devices. Figure 1 shows an instructor pointing out to a class one of the many features of the process.

Use of trainer

Each of the instruments located on the panel of the trainer has a movable pen or indicator, just as in the real instrument. The indicators, positioned by hand, stay where placed, permitting the instructor to set up any given problem on the trainer, explain it fully to the class, and illustrate the way in which the process would react from that point on.

Electrical circuits are functional. High and low alarm contacts inside instruments, pushbuttons mounted on the panels, indicator lights, and alarm horns are connected to simulate operating circuits, interlocks, and alarms. General-purpose power racks, which support the panels and are mounted on casters for ease of handling, supply the specific interlock circuits mounted on the back of the control panels. One of the racks which contain the electrical power supplies and alarm circuitry is visible behind the three-panel section shown in Figure 1.

For flexibility, portability, and savings in the overall cost of the equipment, the panels are arranged separately without instruments. Holes to accommodate the panel-mounted instruments are provided in each panel. Figure 2 shows a wooden crate, used for both storage and shipment.

For economy, training is limited to one portion of the control room at a time. Thus only enough simulated instruments are provided to equip any three adjacent sections of

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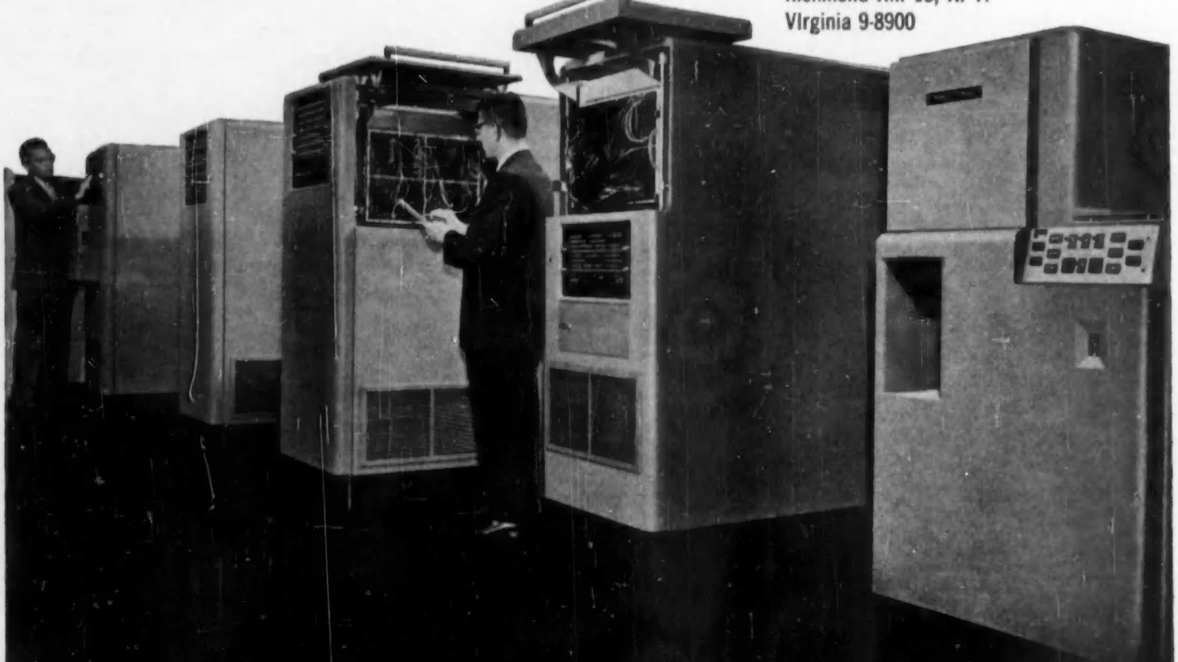


the control panel. This makes it possible to set up specific sections of the control room rather than the whole room. The three adjacent sections permit any of the basic operating portions of the plant to be simulated. And only three electrical racks are used. In less than four hours it is possible to knock down the existing simulating section and set up on the trainer an entirely new portion of the control room.

The process trainer has many other advantages. It is possible to familiarize a group of students (potential operators) with the control room of the plant before the control room has even been built. Students can become skilled in the operation of the various devices in the room without having to worry about spoiling one pound of product. The cost per hour of operating the trainer is essentially negligible. Conditions or sequences of events which could lead to accidents or malfunctioning of the process can be illustrated and corrective means demonstrated. This is particularly important because it keeps the future operators aware of safety hazards and the need for continual vigilance. The student can easily operate the trainer by himself, using it as a training aid. This type of self-instruction is particularly important.

One most important feature of the process trainer is its ability to convey information to the student quickly and without error. Another is its value in showing how much of the essential information the student has assimilated in usable form. This is called "playback". An instructor can tell a student how to operate the process and then show him how to do it, and the student can recite what he has been told and repeat the actions of the instructor. On playback, the student may get excited and forget all that he has been told. The process trainer makes it easier to develop confidence and dependability and thus assure having the right men in the control room.

Another feature of the process trainer is the assistance which it gives the instructor in obtaining the class' attention and participation.

Students can easily demonstrate the procedures or steps which they would take if they were faced with a given problem. Thus a spirit of friendly competition maintains interest and improves memory.

Other advantages

The use of the process trainer has resulted in tangible savings in several areas. The first and most obvious is better training in less time. Another is safer plants. Possible hazardous conditions that were not recognized during the blueprint stages of design are brought to light. Also, the people being trained are more able to appreciate hazardous conditions and potential sources of accidents because they are permitted to stray on the trainer into "hazardous" situations, intolerable in the operation of the real plant. Another source of savings is the check on functional design of the plant. The fact that the instructor and his students must reason out what will happen while they operate the process trainer leads to a better understanding of the mechanisms involved. In this case, it led to the discovery of several points of inconsistency in the design of the plant that was simulated. The process trainer has been well received by all who have seen it and used it. Before it was put into service, there were some who felt that its cost would be hard to justify, especially since the real plant would be available to train operators. These people, almost without exception, reversed their opinion once the trainer was on hand and put into use. It is likely that once purchased, a process trainer will continue to be of use in training replacement and part-time operators.

As chemical plants become more complex and production speeds increase, it is likely that process trainers will incorporate complete analog computer facilities so that the control room instruments actually perform as they will in the real plant. The components are available today; economic justification is not far off.

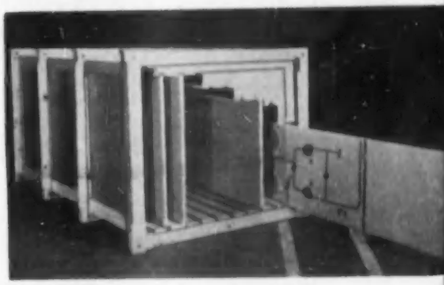


FIG. 2. Unused sections of trainer store in shipping crate.

Digital Machine-Tool Control Simplified

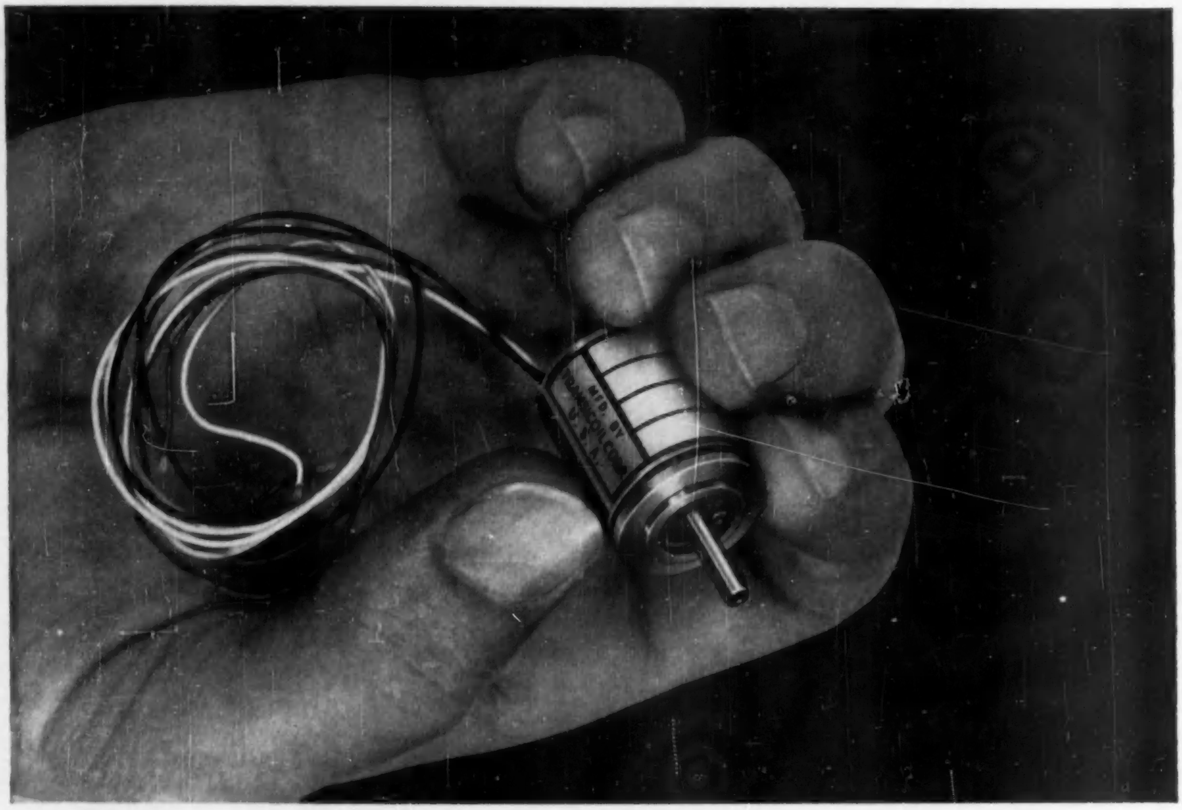
THOMAS J. THOMAS
Kearfott Co., Inc.

Here is a simple "do-it-yourself" kind of digital machine-tool control system. Relays are used, rather than vacuum tubes. Punched-card input controls positioning by lead screw to 0.0025 in.

Fundamentally, automatic machine-tool control resolves itself into a problem of accurately positioning a workpiece from a comparatively inaccurate, inexpensive, and easily produced master, such as a punched card. Figure 1 shows a simple solution (X-coordinate section shown only).

The sequence of operations for this system is as follows. The comparator relay tree receives an encoded signal from the punched card through the card reader, which represents the desired X coordinate. This signal, in the form of a true binary code, is compared with the position of the workpiece monitored by the mechanical analog-to-digital converter (Kearfott ADAC) geared directly to it. The comparator relay tree compares these two codes, digit by digit, starting with the most significant digit and proceeding to the least significant digit until a null signal results. As each digit is compared, an electrical voltage is sent to the workpiece drive motor, which in this case is a two-phase high-performance servomotor. This signal drives the motor in the proper direction to obtain a null on the a-d converter, bringing the workpiece into the desired position for the machine operation. This same sequence of operations is then followed for the Y coordinate.

Having automatically positioned the



NEW MINIATURE SERVO

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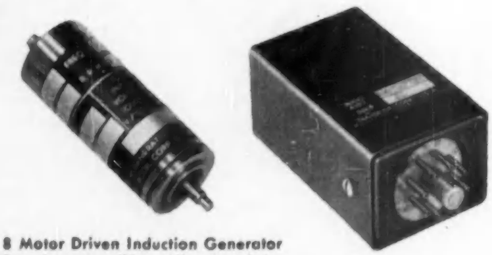


Size 8 Motor Driven Induction Generator and Transistor Amplifier. All units of the Size 8 system have been designed for maximum performance in minimum space.

Here, no bigger than your thumb, is the smallest *practical* servo control motor currently produced. Combined with Transicoil's new Size 8 motor driven induction generator, and powered by a new completely-transistorized servo amplifier, this motor offers you the unusually high torque-to-inertia ratio of 28,000 radians/sec^2.

Compared with a Size 9 control motor—until now, the smallest practical unit available—Transicoil's new Size 8 measures only 0.75 inches in diameter, 10% smaller, and weighs only 1.4 oz., 40% lighter. Yet it operates on standard voltages from 26 to 52 volts, and 52 volts with center tap, at 400 cps, permitting push-pull transistor application.

Hence, just as Transicoil's introduction of plate to plate wiring eliminated the transformer, once necessary in servo systems, the Size 8 units and transistor amplifiers mark another milestone in miniaturization.

This is just one more example of how Transicoil can solve your control problems whether they involve miniaturization or control complexity, and go on to manufacture systems and components of the utmost precision and accuracy. You pay only for results—on a fixed fee basis for equipment delivered and performing properly.

Technical data on the new Size 8 combination and the transistorized amplifier is yours for the asking. But you'll end up with a better system if you write outlining your servo control problem.

TRANSICOIL CORPORATION

Worcester, Montgomery County · Pennsylvania

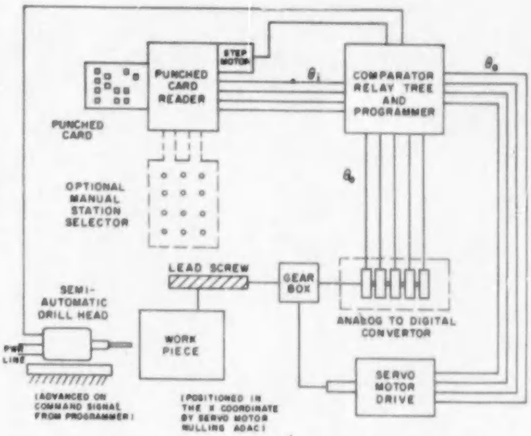


FIG. 1. Punched-card programmed digital machine-tool control systems.

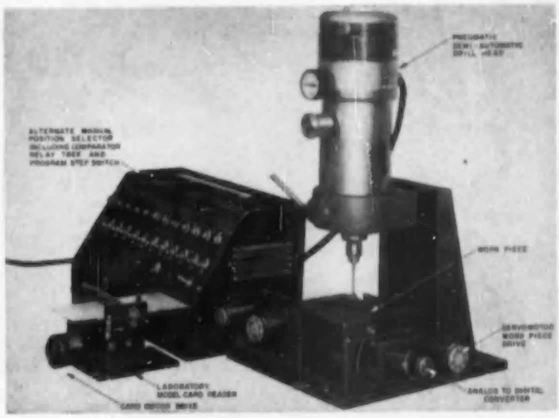


FIG. 2. Laboratory model of a digitally-controlled drill press.

work, the program switch signals the drill press to automatically lower itself and drill the desired hole. The drill head used in the laboratory model (Figure 2) is driven by a pneumatic pressure. The semi-automatic drill retracts after drilling a hole to a preset depth. After the drilling operation, the programmer advances the card to the next position to repeat the sequence above until all the holes coded on the punched card have been drilled. The programmer in the lab model is a simple stepping motor operating a multi-wafered switch.

Comparator

The digital comparison between input and output is done by the relay tree shown in Figure 3. Besides comparing the input and output digit by digit, the relay tree converts cyclic binary from the a-d converter to true binary prior to comparing it with the true binary command signal. Cyclic binary eliminates the ambiguity inherent in true binary coding.

The comparator and digital code conversion for the 12-track digital encoder used in the laboratory model required 12 four-pole double-throw and 12 double-pole double-throw relays to accomplish the above.

Any disagreement between the converter and the card input applies voltage to the servomotor (Kearfott R160) to drive the converter into coincidence with the card input. Direction sensing is built into this circuitry. No vacuum tubes or other means of amplification are required.

The output of the comparator relay tree drives the servomotor, which positions the lead screw through a 10.35:1 ratio gearhead. The a-d converter is directly coupled to the lead screw (Figure 1) through a 2.8:1 gear ratio and is simultaneously positioned by the motor while driving the workpiece into position. One revolution of the converter shaft equals 16 bits. Therefore, since the lead screw makes ten turns per inch of advance, each inch is divided into 448 parts. The digital capacity of the converter is 4,096 bits, precisely resolving the 9-in. lead screw into 4,096 parts, or better than plus or minus 0.0025 in.

Data comparison

The codes are compared digit by digit, starting with the most significant place. While this is being done, the errors at the less significant places are kept from driving the servo by means of a "suppressor" circuit. The servo is so designed that when the input signal is "1" and the equivalent true binary value of the slip ring readout is "0", the drums are driven in an increasing direction to null. Conversely, if the input is "0" and the equivalent readout is "1" the drums will be driven in a decreasing direction. After the most significant digit is in agreement with the input, the next digit is compared and nulled in like manner. This operation continues until the readout agrees with the input, correct to the least significant digit.

For example, take an arbitrary shaft position represented by arabic number 39, whose true binary representation is 100111. If the input code is 010011, it will be seen, as explained below, that the shaft is steadily driven in the decreasing direction (from 39 to 29). Thus, the most significant digit will be driven from 1 to 0, until the number reaches 31. Since the following three digits are identical, an error in the fifth digit will cause the shaft to rotate (still decreasing) until the 29 is reached at which time the sixth digit is also satisfied.

The servo is always driven in the proper direction to nullify the error without hunting. This is possible only with the true binary system; other number systems do not contain this logic. Since digits are compared and nulled individually, the disadvantage of the true binary system, i.e., ambiguity between digits, disappears.

Manual operation

A manual operating panel can easily be adapted to this method of control simply by providing a pushbutton input to the relay comparator representing the desired station. In this case it would take 12 pushbuttons, one for each digit. By actuating the correct pattern of pushbuttons, any position could be inserted, with a resulting resolution of plus or minus 0.0025 in.

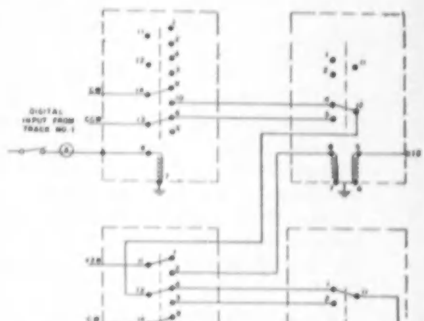
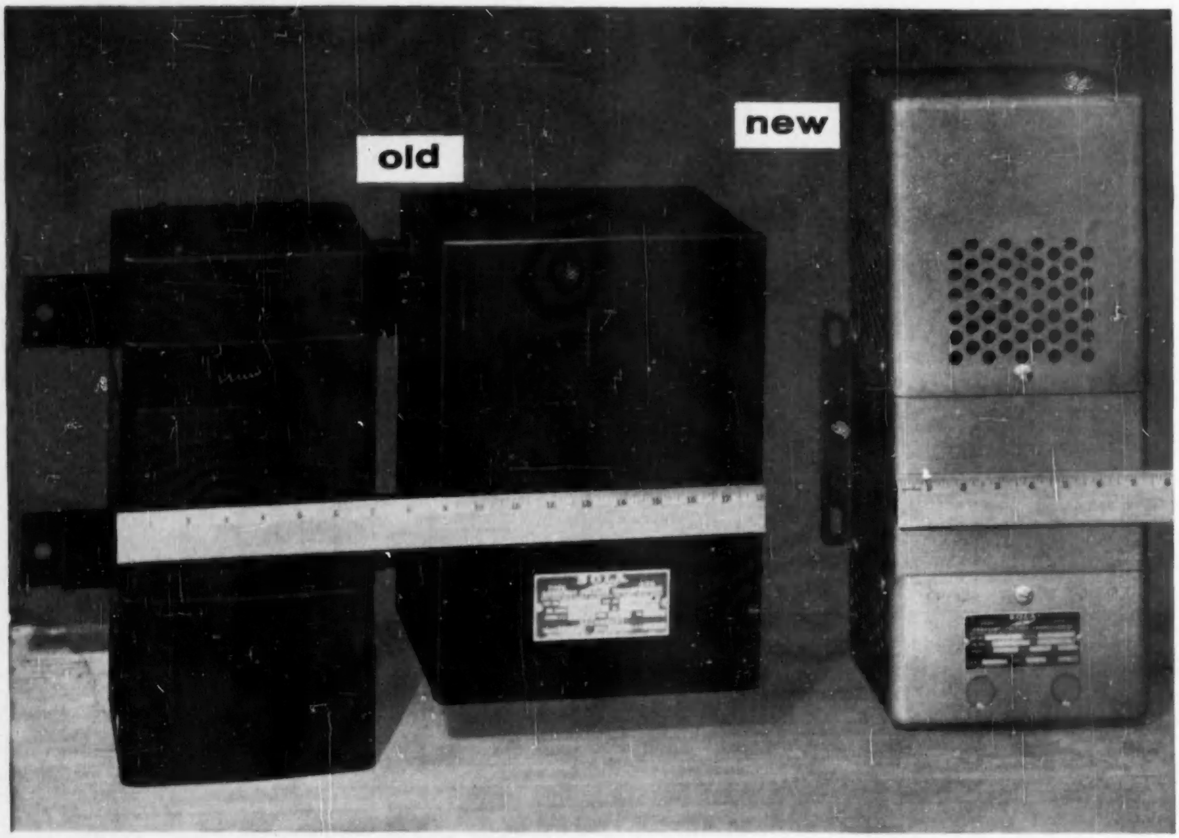


FIG. 3. Relay tree circuit used in comparator.



SMALLER SIZE, LIGHTER WEIGHT *of the new Sola Type CVH regulating transformer design is shown by the comparison of 1000va units shown above. The new unit shown at the right utilizes a single, rectangular housing that replaces the core-and-coil-assembly and separate neutralizer component. Also available in the new design are 250 and 500va capacities. Finish is gray hammerloid.*

New Sola Harmonic-Neutralized Constant Voltage Transformers greatly reduced in size and weight

Now the valuable performance features of the Sola Harmonic-Neutralized Constant Voltage Transformer (Type CVH) are offered in a new unit design that provides up to 60% reduced size and 54% lighter weight. In addition to significant size and weight reductions, the new Sola Type CVH regulator design provides the lowest external field of any stock static-magnetic stabilizer available.

Essentially, electrical characteristics of the new Type CVH regulator are unchanged. Stabilization is ±1% regardless of primary voltage swings over a newly-expanded range of 95-130 volts. Sinusoidal output is delivered with less than 3% harmonic distortion at rated load. The nominal output rating has been raised to 118 volts to correspond with similar input reratings of electronic and other equipment.

Sola harmonic-neutralized regulators may be used for the most exacting applications with equipment having elements which are sensitive to power frequencies harmonically related to the fundamental. They are especially suitable for input to a rectifier when close regulation of the dc output is required.

New design Sola Type CVH regulators are available in three capacities — 250, 500, and 1000va. For specific advice on your particular application, consult your Sola representative listed below.

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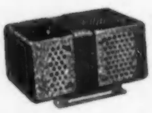

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TWO IDEAS in Vibration Testing Instrumentation

1. ACCELEROMETERS SIMULATE TUBES

Special accelerometers measure vibrational forces at electron tube elements as transmitted via the tube socket. The accelerometers simulate tubes in size and shape, and plug into the tube sockets.

O. A. BIAMONTE
Signal Corps Engineering Laboratories, and
A. W. ORLACCHIO
Gulton Industries, Inc.

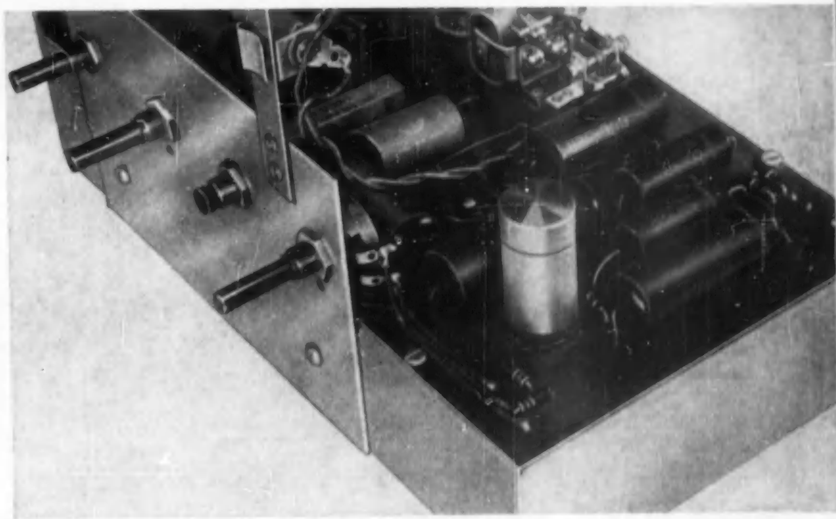


FIG. 1. Special accelerometer plugs into tube socket to simulate miniature electron tube.

Accelerometers mounted on the chassis at a tube socket location very often give a poor picture of the forces encountered by the elements of a tube mounted in that socket. The reason is that vibrational accelerations can be transmitted through the socket to the tube and multiplied by whatever mechanical lever arms are present. Thus, chassis that have been vibration tested in the normal way and found satisfactorily within tube manufacturers' acceleration limits can cause tube failure in practice due to excessive acceleration of the tube elements.

To determine the acceleration forces that actually exist at the tube elements on a vibrating chassis, special accelerometers have been built that simulate the size and shape of various standard electron tube configurations. These accelerometers are mounted on standard tube bases at the same height above the base as the elements of the tube being simulated. They are plugged into the socket in the same way as the tube so that vibration is transmitted to them in the same manner, Figure 1.

Originally, the Signal Corps required that the accelerometers be omnidirectional and simulate the tube elements in both size and weight. During the progress of the development, the omnidirectional approach was abandoned in favor of three mutually perpendicular seismic elements in each accelerometer

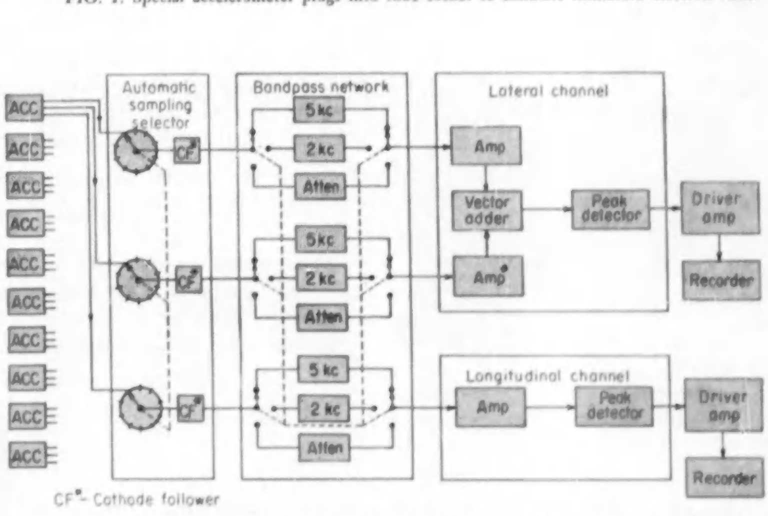


FIG. 2. Programmed system for automatically recording data from accelerometers.

housing. The Z axis of the Cartesian coordinate system thus formed lies along the longitudinal axis of the tube. The X and Y axes are in the lateral plane perpendicular to the longitudinal axis.

A test system has been designed to automatically record the outputs of up to 20 of these special accelerometers in sequence. In this system, the X and Y signals from each accelerometer are added vectorially and the sum is recorded. The Z signal is recorded directly. The system is diagrammed in Figure 2.

In the automatic sampling selector, the switch has six 10-position sections which are grouped in pairs. The outputs of one accelerometer at a time are connected to the cathode followers. All other connections are grounded. The switch is ratchet-driven by a Ledex rotary solenoid progressively stepped by a motor-driven cam switch.

The filter networks consist of three units, one for the longitudinal input and two for the lateral input. Each unit has a 2-kc filter, a 5-kc filter and a 6-db attenuator. Any of these filters or attenuators can be switched into the circuit manually.

The main components of the longitudinal channel are an amplifier and a peak detector. In the amplifier it is possible to change the gain by use of a voltage divider; this permits the selection of a unit having full-scale sensitivity of either 2, 5, 20, 50, or 100 g's. Following these amplifiers, there is a double diode which operates as a peak detector. One diode indicates positive peaks, the other negative peaks. The magnitude of all peaks are then permanently recorded for analysis.

The lateral channel operates in fundamentally the same way as the longitudinal channel. However, following the amplifier, which is similar to the one used in the longitudinal channel, there is a vector adder. Here, the amplified X and Y signals are passed to phase splitters. The four output signals of the phase splitters are then modulated with a 3-megacycle carrier, each in a separate modulator tube. The outputs of the four modulators are phase-shifted in a three-section delay line. Each section shifts the signal by 90 deg. These signals are added in a common impedance, and the sum is amplified and sent to the peak detector circuit.

Provision is made for monitoring individual filtered outputs of the seismic elements of any accelerometer. This permits the gathering of data which can be put on tape and which, when processed, can give a frequency-vs.-amplitude analysis at a specific socket location.

This equipment has been under evaluation at the Signal Corps Engineering Laboratories for several months. Figure 3 shows a typical test setup. While it is not yet used in the field by equipment manufacturers, it promises to be a useful tool for the evaluation of shock and vibration problems regarding electron tube and electronic chassis design.

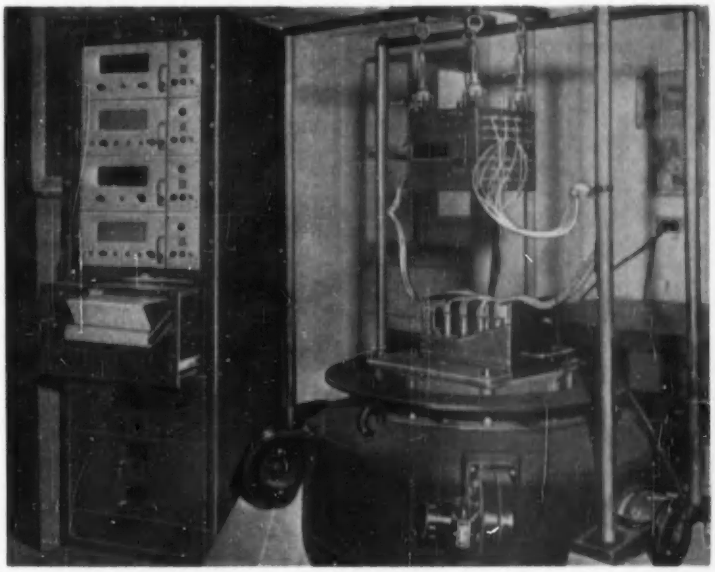


FIG. 3. A typical test setup for vibration testing an electronic chassis. In this case leads are brought out from the tops of accelerometers that simulate tubes.

2. SHAKE TABLE OPERATES IN WIDE TEMPERATURE RANGE

K. M. MILLER, LearCal Div., Lear, Inc.

Temperature affects the stiffness, hence the mechanical resonance, of many materials. A new test chamber, vibration-isolated by means of a neoprene bottom, permits the specimen undergoing vibration tests to be heated to plus 125 degrees C, or cooled to minus 55 degrees C.

Unsuspected mechanical resonances, which might quickly destroy assemblies subject to vibration in service, can be detected by vibration test. Steps can then be taken to control the resonances. These tests are normally made at room temperature, however, and the data may be entirely invalid at other temperatures.

A simple temperature chamber has been developed which can be added to a shake table and which allows vibration tests to be made over the range from minus 55 deg C to plus 125 deg C. The equipment used consists of commercially available con-

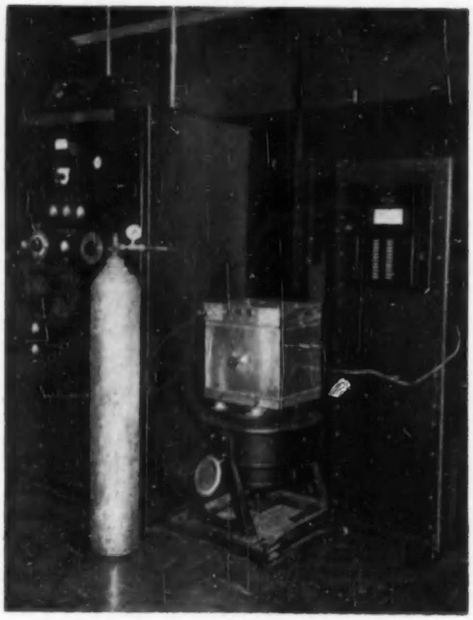


FIG. 1. Shake-table setup with temperature test chamber in place.

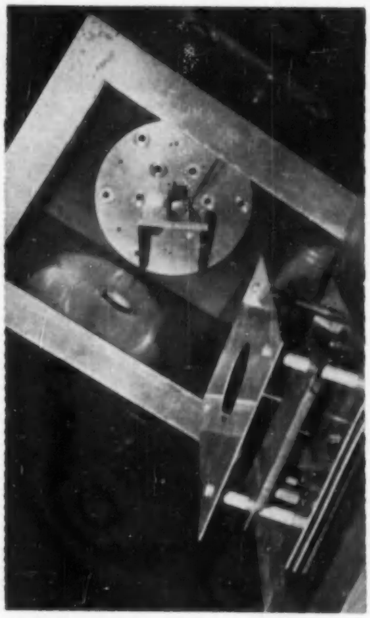


Fig. 2. Interior of test chamber shows small transformer mounted for testing.

trol components and a specially constructed chamber. Control is accurate to plus or minus 2 deg C.

Figure 1 shows the laboratory setup. At left is the shake-table control unit. Just in front is a CO_2 bottle. CO_2 under high pressure is allowed to expand to atmospheric pressure. The corresponding drop in temperature gives control over the low temperature range. In the center is the shake table with the test chamber in place. At right is a relay rack in which the temperature controller is housed.

Figure 2 shows the cover and the interior of the test chamber. A small transformer is in place in the test chamber ready for testing. On the cover can be seen two 500-watt strip heaters and a fan. The fan provides a uniform temperature distribution when the chamber is in operation.

The control circuit is shown in Figure 3. On-off control is used and the operator can select a hot or cold test condition. A switch on the heaters permits operation at either a high or a low rate.

The mounting of the test chamber is of special interest. The four sides of the chamber are mounted to the shake table frame by means of vibration isolators. The bottom of the chamber is a sheet of neoprene rubber through which the shake table proper extends. Thus the test chamber with its connecting wires is subjected to little vibration itself.

The cover of the test chamber contains the necessary control elements. A stem thermometer is added to one side of the chamber and a pressure gage is used on the CO_2 bottle.

The unit has been in operation for over a year and has given excellent service.

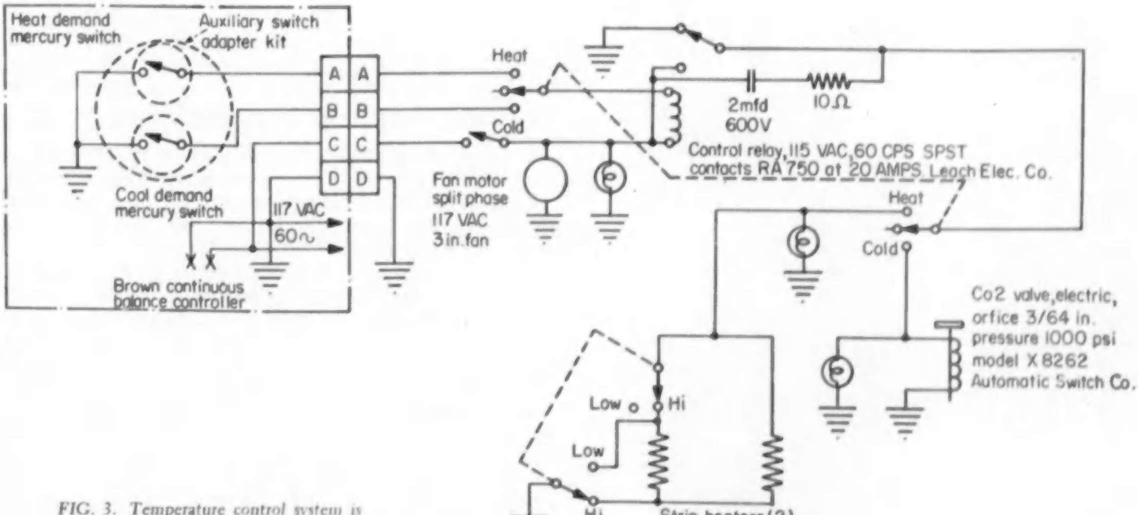
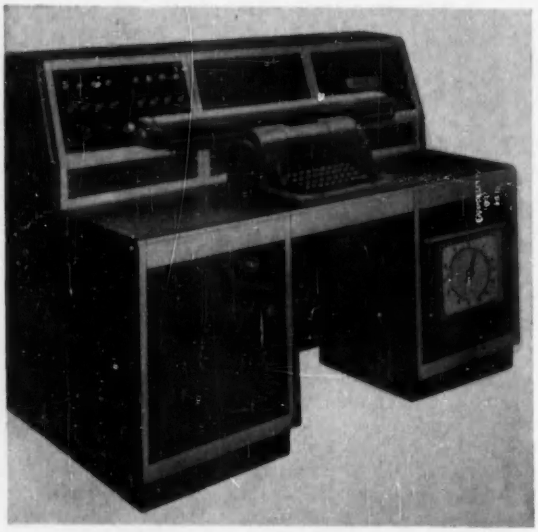


FIG. 3. Temperature control system is straightforward on-off controller. Hot or cold selection is made and set-point chosen manually.

NEW PRODUCTS

LISTING IN GROUPS



Housing a number of time-tested components, this attractive logger features an extremely flexible input section. Its official unveiling will occur at the Automation Show in New York City.

UNIVERSAL LOGGER is packed with flexibility.

Called the DATA-LINER, this brand new universal logger is of building-block design, its standard instruments providing reliability and ease of maintenance.

The console (photo left) houses the following components:

▶ As many as nine input adapters to change primary transducer signals into appropriate 60 cps ac signals, and perform numerous auxiliary functions.

▶ A basic encoding unit that indicates the value of the input signal and converts it to digital form.

▶ An input programmer that will handle inputs from 48 primary elements, select the format for printing, and control subsidiary functions.

▶ An output programmer that controls the operation of one or more input programmers and also controls the typewriter.

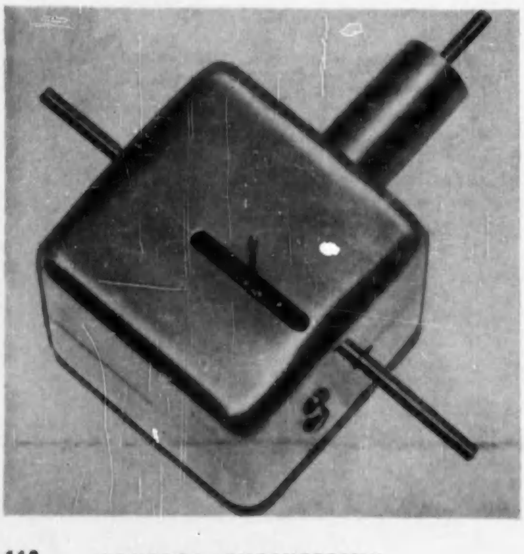
▶ A digital clock to indicate time in digital form, and provide signals for time-typing and periodic logging.

▶ A regulated dc power supply for typewriters, relays, stepping switches, and rotary solenoids.

▶ A regulated, filtered ac supply for operating one or more ac adapters.

Thermocouples, strain gages, resistance bulbs, and many other primary elements are easily accommodated by the versatile input section.—Hanson-Gorrill-Brian, Inc., Glen Cove, N. Y.

Circle No. 1 on reply card



INTEGRATOR is an ISA prize winner.

This device took second prize in the data handling section of the "New Ideas in Instrumentation" contest at the ISA show in New York. A mechanical integrator, it consists basically of a disc, drum, and floating ring. In operation, an input shaft drives the disc which in turn causes the floating ring (mounted perpendicular to and in contact with the disc) to rotate at a speed proportional to its distance from the center of the disc. Situated at a right angle to the axis of the input shaft, perpendicular to the plane of the floating ring, and in contact with the inside edge of the ring is the drum. The output shaft is merely an extension of this drum. Thus the speed of the output shaft (speed of the drum) is directly proportional to the product of input speed times the displacement of the ring from the center of the disc. A constant of proportionality is also required to account for the ratio of disc and drum diameters. Some uses include variable speed drives and ratioing mechanisms.—Optimum Engineering Co., Inc., Grand Prairie, Tex.

Circle No. 2 on reply card

PILOT OPERATED air valve is electrically safe.

This attractive double solenoid air valve utilizes a spool-type pilot. When one solenoid is energized, the spool moves, causing the main valve to shift. The main valve will then stay in this position until the second solenoid is energized, causing it to shift back to its original position. This prevents the valve from reversing in the event of an electrical failure. Solenoid enclosures are waterproof and airtight; valve covers are chained to the body. Recessed pins at either end permit manual operation without cover removal. For safety, the valve is electrically inoperative when the covers are removed. Available sizes are ¼ in., ⅜ in., ½ in., and ¾ in.–Automatic Valve Co., Farmington, Mich.

Circle No. 3 on reply card

POWER SUPPLY has a double function.

Designed to provide either constant current or constant voltage, this compact portable power supply should prove useful in semiconductor and electronics research as well as in general laboratory work. The required current or voltage remains at the selected value under varying load or line conditions. Regulation is provided by feedback loops, a control amplifier, and series regulator tubes. The output is monitored by a multi-range combination voltmeter-milliammeter. For constant current the voltage adjusts itself between 0 and 400 volts. For constant voltage, current ranges from 0 to 200 ma.–Matthew Laboratories, Yonkers, N. Y.

Circle No. 4 on reply card

PRESSURE PICKUP is stable and versatile.

This unit measures dynamic pressures of complex waves from sonic vibrations, blast pressures, and water hammer in pipe lines. Dynamic pressure auuplied to the diaphragm of a sealed liquid-filled cell causes an infinitesimal amount of polar liquid to flow through a porous disc, generating an electrical signal. This is known as "streaming potential". Operating pressures range from 0.0001 to 100 psig. The unit is said to have a flat response between 3 cps and 25,000 cps. Oscillations in this frequency bracket produce electrical signals in phase with and proportional in amplitude to the pressure. A high output and a very low internal impedance are additional characteristics.–Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 5 on reply card

TRANSISTORS convert signals for telemetering.

This compact converter accepts variable frequency input signals from turbine-type flow meters or ac tach generators and changes them into a 0.5-volt signal suitable for telemetering. The unit is intended for use in guided missiles and piloted aircraft where flow rates of propellants, jet fuel, engine oil, and hydraulic oil must be telemetered to the ground. It uses seven transistors and is housed in a 3 in. by 2 in. by 2⅛ in. box with a single aircraft-type connector. Output, said to be linear within 0.2 percent of full scale, varies less than 0.2 percent for a 5-percent change in the supply voltage. Temperature range is minus 60 to plus 170 deg F. Span adjustment is included to give 5 volts output. –Waugh Engineering Co., Van Nuys, Calif.

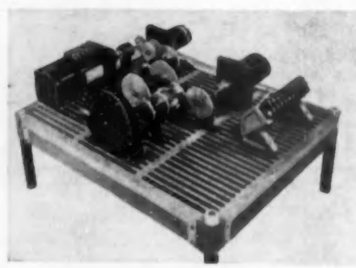
Circle No. 6 on reply card

RESEARCH, TEST & DEVELOPMENT

FOR FIELD TESTS

Control amplifiers can be quickly field-tested by this compact portable analyzer, which connects to the amplifier through a tube socket plug adapter without disturbing either the input or output connections. Check-out procedure consists simply of sequencing a selector switch and observing the corresponding waveforms on the analyzer screen.—Parameters, Inc., New Hyde Park, N. Y.

Circle No. 7 on reply card



FOR BREADBOARDERS

This typical servo-system mockup was constructed from breadboard components now being marketed by Helipot. Included in the recently acquired line are such parts as grid plates, shaft hangers, couplings, limit stops, dial assemblies, gears and differentials, as well as such special items as magnetic clutches and ball-disc integrators. In addition to individual parts, kits are available containing a carefully selected assortment of the most frequently used parts.—Helipot Corp., Newport Beach, Calif.

Circle No. 8 on reply card

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Bendix
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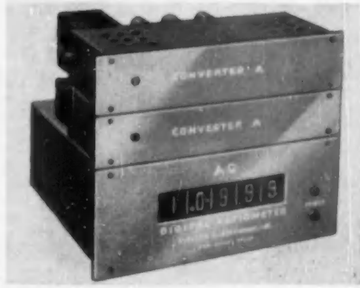
NEW PRODUCTS



AC RATIOMETER

This completely automatic ac ratiometer will measure, with no phase-shift error, the ratio of two ac voltages, E_1 and E_2, where E_1 is derived from E_2 and E_2 drives both the bridge of the ratiometer and the test unit. Measurements are displayed digitally on the in-line five-digit readout. In operation, ac voltages are converted to dc, and the dc voltages presented. The instrument is suited for transformer testing, precision tachometer and resolver testing, and for checking ac networks. Suitable for rack mounting, the panel measures 14 in. by 19 in.—Electro Instruments, Inc., San Diego, Calif.

Circle No. 9 on reply card

LOG CONVERTER

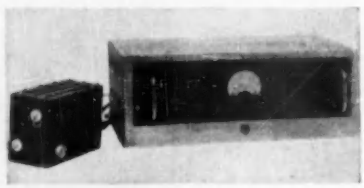
Available in either desk top or rack mounting form (as shown here), this new logarithmic converter accepts ac or dc input voltages and provides a dc output proportional to the logarithm of the amplitude of the input voltage. This type of presentation has the advantage of permitting the plotting of wide-level ranges with maximum accuracy at low amplitudes. Power supply is self-contained. Input attenuator has five steps of 0, −10, −20, −30, and −40 db, allowing input ranges from 0.001 to 100 volts. Dynamic range is better than 60 db, and accuracy over the combined frequency and amplitude range is within plus or minus 0.5 db.—F. L. Moseley Co., Pasadena, Calif.

Circle No. 10 on reply card

SECONDARY STANDARD

Available as a portable unit or in a 14-in. rack-mounting model, this secondary-standard voltage-reference source combines a dc voltage source with five decade switches as incremental voltage dividers. It features continuous dc reference outputs of plus or minus 100 volts, accuracy within 0.01 percent, and a maximum drift of 0.02 percent per year. Besides its use for precision voltage measurements, the unit is well suited for use as an analog computer absolute reference source, for meter and transducer calibration, and as a low-impedance attenuator.—Epsco, Inc., Boston, Mass.

Circle No. 11 on reply card

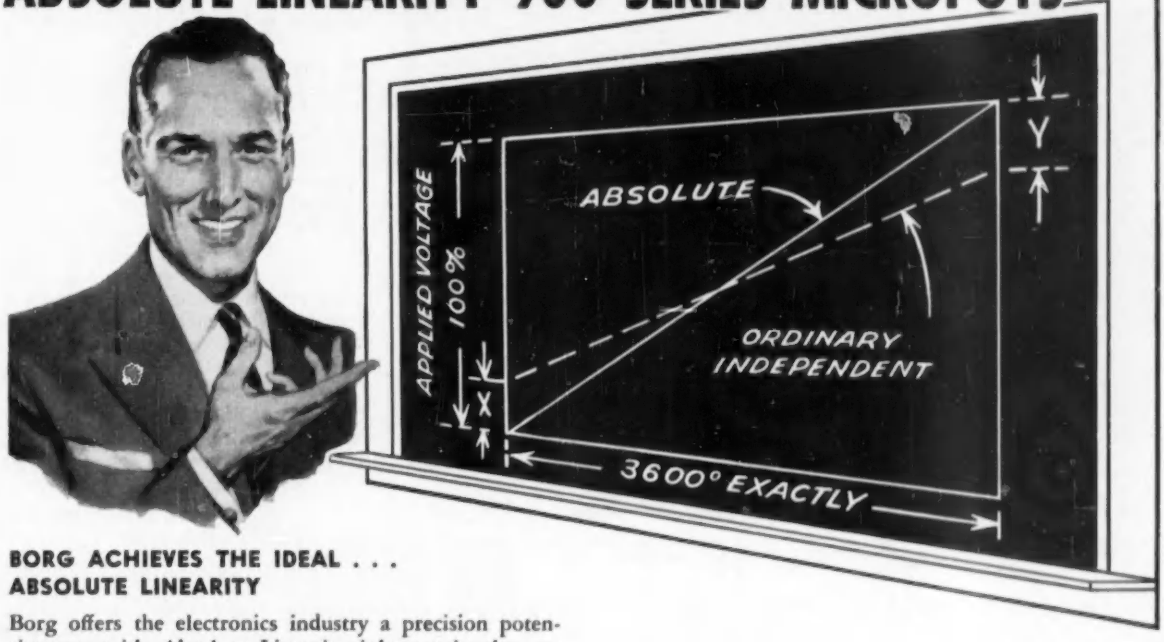


REED METER

Developed for ionization current measurements requiring a high order of stability and precision, this vibrating reed electrometer is said to be ideal for critical measurement of small dc currents and voltages at high impedance, e.g., those encountered in radioactivity and pH studies. Stability of the instrument is within plus or minus 1 mv, day-to-day. Ranges are 0.30, 0-100, 0-300, and O-1,000 mv. Complete with cables, the entire unit weighs only 29 lb.—American Tradair Corp., Long Island City, N. Y.

Circle No. 12 on reply card

NO TRIMMING NECESSARY WITH BORG ABSOLUTE LINEARITY 900 SERIES MICROPOTS



BORG ACHIEVES THE IDEAL . . . ABSOLUTE LINEARITY

Borg offers the electronics industry a precision potentiometer with Absolute Linearity inherent in the pot itself. It requires no trimming of any kind!

THE END OF UNCERTAINTY

Embodied in Borg's new 900 Series 10-turn and 3-turn Precision Potentiometers are exclusive advantages that provide this high degree of accuracy. You get from zero to 100% of applied voltage over exactly 3600° (or 1080°) of shaft rotation.

This means no such parameters as electrical rotation tolerances, end resistance or jump-off resistance need be considered error in output. Many doors, formerly closed to electronic design engineers, are now opened by Borg Absolute Linearity.

ORDINARY INDEPENDENT LINEARITY

Note the line marked "Ordinary Independent" on the blackboard diagram. This line is unable to go to zero and 100% of applied voltage because of X and Y known as end resistances. Therefore, trimming is required to compensate for the potentiometer errors of end resistances X and Y.

Now, note that the line marked "Absolute" goes through zero applied voltage output at zero shaft rotation and through 100% applied voltage output at 3600° of shaft rotation. This is the reference line for absolute linearity and is inherent in the Borg 900 Series potentiometer. Thus Borg achieves absolute linearity without trimming of any kind.

SIMPLICITY ASSURES RELIABILITY AND ACCURACY

Simplicity of the Borg 900 Series Micropot affords greater accuracy and reliability. It eliminates such possible sources of error as trimming errors, unstable trimming, resistances, etc. Another Borg advantage simplifies assembly and reduces possibility of error. The Borg CCW mechanical stop is set up to provide a phasing point. This exclusive advantage reduces field replacement to the purely mechanical process of attaching leads and phasing from the present stop.

ABSOLUTE LINEARITY REDUCES COST

The accuracy and reliability of your equipment is improved with a Borg 900 Series potentiometer which also effects a savings in time and money. Your cost is lowered by eliminating trimming resistors and the technically trained labor competent to install them.

Many other advantages of the Borg 900 Series can help solve your potentiometer problems as they are now doing in all types of equipment from jet engines to steel mills.

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NEW PRODUCTS

TORQUE VS. SPEED

A complete line of motor testing dynamometers, featuring electronic tachometers, is now on the market. The dynamometers employ a basic torque indication system that is independent of speed, rotor bearing friction, and external sources of mechanical or electrical error. The entire brake assembly is carried on ball-bearings, with extremely low static torque drag. The electronic tachometer is essentially a four-digit-glow transfer-tube counter, with a cycle timing gate to control the count-read-reset cycling. Since the tachometer uses a photoelectric pickup mounted on the rear of the dynamometer, it requires no driving torque, hence cannot introduce error.—Magtrol, Inc., Buffalo, N. Y.

Circle No. 13 on reply card

SEE FAILURE OCCUR

The portable instrument shown here permits putting shake tests into slow motion for observation by automatically synchronizing stroboscopic lights with vibration exciters. It yields not only the simple fact of failure, but also the exact cause. In operation, it controls the time-position of the strobe flash with respect to the shake frequency signal. Slow-motion rate is continually adjustable from ¼ to 3 cps by front panel control.—Chadwick-Helmuth Co., Monrovia, Calif.

Circle No. 14 on reply card

UPS READABILITY

Readability is greatly improved in these new voltmeters by expanding the scale in the range most used. As a conse-

RELIABILITY...ACCURACY...
AUTOMATIC MEASUREMENT
AT NEW LOW COST

Available in either portable (shown) or rack mount models

ALL DESIGN FEATURES of higher priced NLS instruments now are available in the low cost Model 351 Digital Voltmeter for applications requiring 3-digit measurement. This economical model offers the *same range* as the *widely-used* NLS Model 451 (4-digit), recognized standard of the industry. It has the same exclusive NLS *oil-sealed* stepping switch system that guarantees maximum trouble-free life. Its performance offers *automatic measurement* from zero to ±999 volts d-c with high accuracy and resolution. And it has automatic polarity indication, automatic range selection, automatic readout decimal point location. *Fast readings* are flashed in brilliant in-line luminous numerical display. NLS Model 351 Digital Voltmeters *cost only $985*. Investigate today.

CHARACTERISTICS

RANGE	RESOLUTION
Zero to ±.999 volts d-c	±1 millivolt d-c
± 1.00 to ± 9.99 volts d-c	±10 millivolts d-c
± 10.0 to ± 99.9 volts d-c	±100 millivolts d-c
±100 to ±999 volts d-c	±1 volt d-c

ACCURACY: *Equal to resolution*

READING TIME: *0.80 seconds average.*

CHOPPER SAMPLING RATE: *60 cycles per second.*

INPUT IMPEDANCE: *1000 megohms on zero to .999 volt scale; 10 megohms on all other ranges.*

CALIBRATION VOLTAGE: *Standard cell provides EMF constant within ±0.01% from 4°C to 50°C, and usable from −16°C to +60°C, with accuracy of ±.02%.*

REFERENCE VOLTAGE SOURCE: *Internally-mounted mercury cell.*

POLARITY INDICATION: *"+" or "−" automatically prefixes the numerical display.*

READOUT DECIMAL POINT: *Positioned automatically depending on range.*

STYLES: *Rack mount — 5¼" high; 19" wide; 15⅛" deep. Portable—11" high; 8¼" wide; 15⅛" deep.*

WEIGHT: *Only 29 pounds (new, lightweight aluminum construction).*

POWER: *115 ± 10 volts, 60 cycles, 75 watts.*

OPTIONAL ACCESSORIES:
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Manual-command recording controls.
Automatic recording controls to record each reading at completion of balance.

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quence, reading accuracy is also improved. A variety of ranges is available for either ac or dc voltage measurement. The ac movements have wide frequency ranges, good linearity, and true rms readings. A typical meter, for line voltage measurements, has a 0-to-130-volt scale. But the first 90 volts cover only a small segment on the low end of the scale. This permits considerable expansion of the scale from 90 to 130 volts. Models are available in a number of case styles.—Phaostron Instrument & Electronic Co., South Pasadena, Calif.

Circle No. 15 on reply card

SUB-SYSTEMS

CARD CONVERTER

A new card converter automatically translates alphabetically and decimally coded data recorded on cards into binary language for transfer to an electronic digital computer for processing. Called the ALWAC Card Converter after the computer with which it is used, the new unit should greatly increase the system's range of applications.—Logistics Research, Inc., Redondo Beach, Calif.

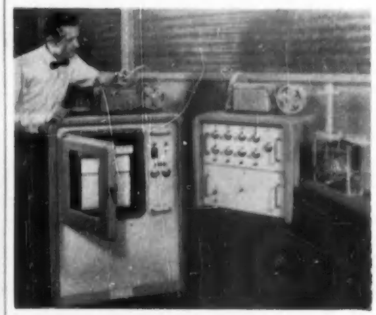
Circle No. 16 on reply card

HIGH-PRESSURE AIR

A new 3,000- to 12,000-psi central compression system is now available for use in the design and testing of pneumatic missile and aircraft control systems. The unit is capable of continuously delivering 54 scfm of air with a dew point of minus 70 deg F or lower. Standard system is a self-contained, semi-portable unit con-

sisting of the compressor, a 50-hp electric drive, controls, filtering and drying equipment, and storage vessels, all mounted on structural steel skids. When the unit must supply a large high-pressure distribution system, storage vessels may be remotely located. Cardox Corp., Chicago, Ill.

Circle No. 17 on reply card



INSPECTION SYSTEM

The system shown above automatically transports, tests, and physically sorts electronic components and keeps records on punched-paper tape. It consists of five basic units: an automatic hopper mechanism; automatic sorter; tester and recorder; analyzer; and a keyboard input to the analyzer. The system will automatically test two samples per second and is accurate to within 0.5 percent. A paper-tape punch records the results. From the tape, the analyzer automatically plots a 16-interval frequency histogram showing the distribution of the tested parts.—Electronic Control Systems, Inc., Los Angeles, Calif.

Circle No. 18 on reply card

MEASUREMENT & DATA TRANSMISSION

DUAL-DAMPED

A potentiometer-type accelerometer has been developed specifically for transonic and supersonic guided missiles and aircraft flight-control applications. The unit is a dual-damped, low-range instrument that resists severe vibration and shock acceleration. Dual damping is accomplished by the

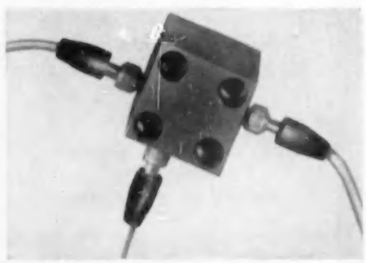
use of a permanent magnet and a silicon fluid. Output of the potentiometer is linear. The wiper, attached to a movable mass, is positioned along the winding as g-forces displace the mass. The ratio of resistance unbalance varies directly with the magnitude of the acceleration.—Genisco, Inc., Los Angels, Calif.

Circle No. 19 on reply card

LOW RESPONSE TIME

The adiabatic temperature probe above is now available with two new fast-response temperature elements for aircraft and missile applications. These provide either a voltage or resistance output proportional to airstream stagnation temperature. Suitable for telemetering or the sensing of data for airborne systems, these instruments offer a recovery factor of 0.985, with response time of 0.25 sec or less. Repeatability is within 0.5 percent. The aerodynamic configuration helps to provide superior performance over the velocity range of Mach 0.3 to Mach 2, at altitudes as high as 60,000 ft.—G. M. Giannini & Co., Inc., Pasadena, Calif.

Circle No. 20 on reply card

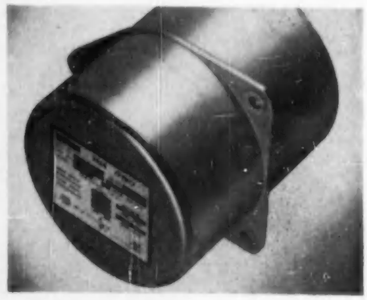


3-IN-1 ACCELEROMETER

This subminiature, high-temperature accelerometer will measure three mutually perpendicular accelerations simultaneously. It will operate in

temperatures from minus 65 to plus 350 deg F, and features an acceleration range up to 500 g, frequency response from 25 to 20,000 cps, and sensitivity of 0.8 mv/g. Although the unit weighs less than an ounce and is less than 1 cu in. in volume, it does the job of three former units.—Gulton Industries, Inc., Metuchen, N. J.

Circle No. 21 on reply card



NEW FREE GYRO

Shown is a free gyro that offers unusual ruggedness and insensibility to mounting and dynamic loads. It features a cast-steel frame mounted solidly inside a structural outer shell having an integral center of gravity mounting flange. Shock specification is 50 g in all axes. Drift rate is less than 18 min of arc per minute, and the potentiometer pickoffs have outputs that are linear within plus or minus 0.5 percent. Angular resolution is 0.09 deg.—G. M. Giannini & Co., Inc., Pasadena, Calif.

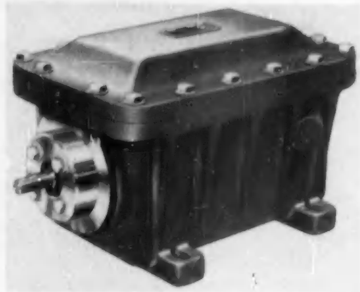
Circle No. 22 on reply card

POSITION TRANSDUCER

Designed for aircraft instrumentation, a linear strain-gage transducer is now available for applications requiring long life, small size, high resolution, and direct input to galvanometers. Only ¼ in. high, the transducer can be externally mounted on aircraft without disturbing the airstream. It consists of two cantilever beams deflected at the free ends by a cam. A shaft extending from the transducer provides external mechanical coupling and internal springs maintain tension on this shaft at all times.—Consolidated Avionics Corp., Westbury, N. Y.

Circle No. 23 on reply card

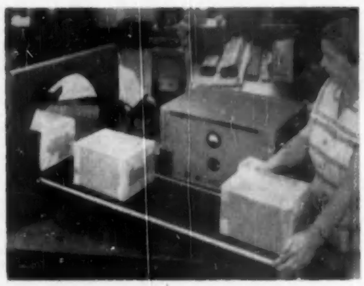
NEW PRODUCTS



DUAL-SIGNAL OUTPUT

The sturdy-looking tachometer pickup shown here features a two-signal system that provides electrical impulses for operation of digital electronic counters, and a three-phase, self-generated electrical output for powering a synchronous tachometer indicator. Where ac or dc analog signals are required in conjunction with the digital information, the three-phase tachometer generator may be replaced by a suitable ac or dc generator. The integral unit has been designed to permit changes to be made in the housing without disturbing the shaft alignment. — I-L-S Instrument Corp., Cleveland, Ohio.

Circle No. 24 on reply card



FOR QUALITY CONTROL

Sensitive to both ferrous and non-ferrous tramp metal particles, the detector being demonstrated above is ideal for the inspection of packaged or bulk material. Typical products which can be inspected automatically at conveyor speeds up to 1,000 fpm are foods, plastics, textiles, rubber, confections, pharmaceuticals, etc. Contaminated material passing through the test coil causes a reject relay to operate in the electronic unit. This same relay can be used to sound a warning, trigger a marking device, or operate a reject gate. Apertures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"Over-run" feature protects regulator against damage if temperature at the bulb accidentally exceeds regulator range.
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can be made any convenient size, and may be mounted in any position.—J. W. Dice Co., Englewood, N. J.

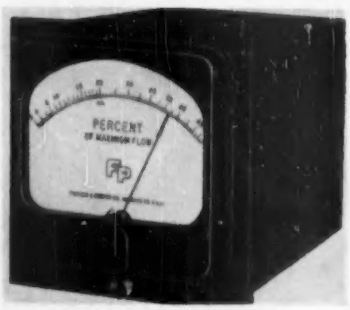
Circle No. 25 on reply card

INFORMATION DISPLAY INSTRUMENTS

DIGITAL INDICATOR

Excellent readability and minimum space requirement are features of this new digital indicator. The unit permits direct reading of signals from a variety of transducers. It can be used for the measurement of temperature, pressure, load, speed, flow, and any other variable that can be translated into an electrical quantity. An electronic null balance servo system drives a set of precision geared number wheels. Nonlinear inputs are linearized by means of a tapped slidewire. Designed for panel mounting, the instrument has a slide-out chassis to facilitate maintenance. Panel space requirement is 7 in. by 7 in.—Performance Measurements Co., Detroit, Mich.

Circle No. 26 on reply card



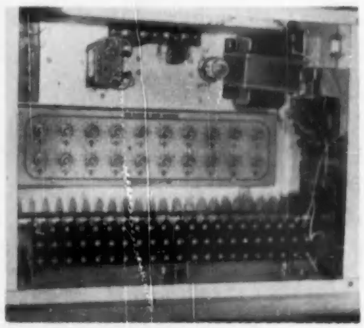
FOR FLOW RATE

Known as the Industrial Logarithmic Panel Indicator, this instrument con-

verts the output signal of a turbine-type flow meter into a series of pulses of constant amplitude at a frequency equal to that of the meter output and, therefore, proportional to volumetric flow rate. These pulses are then integrated in a dc milliammeter, providing an indication that is also proportional to flow rate. External terminals are provided for both the pulse and dc millivolt output signals. A shaded-pole panel meter with a logarithmic characteristic provides uniform rate accuracy within 2 percent, and a short term repeatability of 0.5 percent of rate.—Fischer & Porter Co., Hatboro, Pa.

Circle No. 27 on reply card

CONTROL DEVICES



FOR TIMED OPERATIONS

Called the Timed Operations Preselector, this device is used where a number of timed operations are to be programmed in a preselected sequence or cycle, and where some of these operations must be frequently changed without affecting changes in any of the others. It consists of three basic units: an electronically operated timing device, a control panel with 20 independently adjustable potentiometers, and a rectangular frame carrying a solenoid-actuated shaft with 20 slotted discs. Accuracy of repeat time intervals is within plus or minus 2.0 percent, which is actually plus or minus 0.01 percent of the total time available.—Henry G. Dietz Co., Long Island City, N. Y.

Circle No. 28 on reply card

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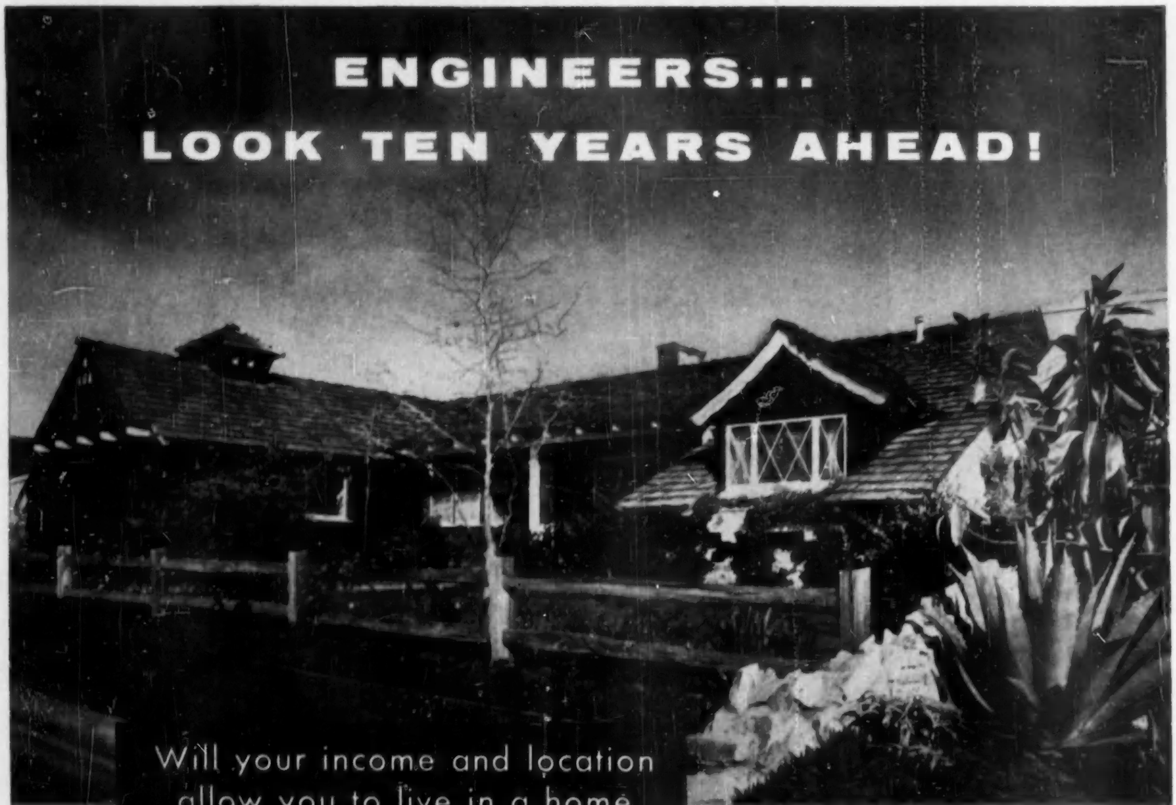

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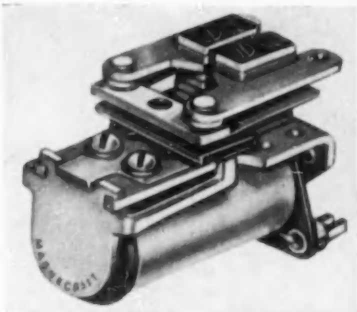
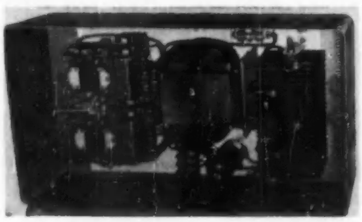


HANDLES HEAVY CURRENT

Reliable switching of heavy current in limited space through long service life is achieved by this new Class 22D telephone-type relay. Specially designed double-break contacts switch up to 20 amp, noninductive load. Contacts are single pole, single throw, normally open. Unit measures $2\frac{1}{16}$ in. by $1\frac{9}{16}$ in. by $1\frac{1}{16}$ in., and is available for operating voltages to 230 dc and 440-volt, 60-cycle ac.—Magnecraft Electric Co., Chicago, Ill.

Circle No. 29 on reply card



AC MOTOR BRAKE

Compact and self-contained in NEMA 1 or 12 enclosures, these new braking systems can be applied to all standard ac motors. Through electrical braking, torque diminishes as the motor decelerates until a smooth, definite stop results, normally in the same time required for acceleration of the driven equipment. To accomplish this, direct current from a selenium rectifier is applied to one phase of any squirrel-cage or wound-rotor motor. A timing circuit allows direct current to flow only long enough to stop the motor. When activated from any desired pilot control, braking begins immediately after the stop signal is received. Reduced capacity taps on a transformer permit selection of the degree of braking desired.—Westinghouse Electric Corp., Pittsburgh, Pa.

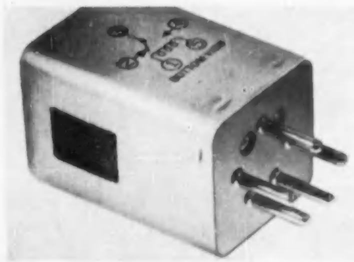
Circle No. 30 on reply card

NEW PRODUCTS

G-LOAD IMMUNE

Designed to pulse at any rate from once to 3,000 times per second, this new signal generator (in hand) is said to be virtually immune to the effects of acceleration loads. In tests it has withstood loads in excess of 100 and has performed accurately despite high vibration levels, high altitudes, and temperature variations within the minus 65 to plus 185 deg F range. Its subminiature tubes are assembled in a sandwich with capacitors and resistors mounted on a printed circuit board. At present, units have a pulsed 150-vdc output that actuates a neon bulb.—Electromation Co., Burbank, Calif.

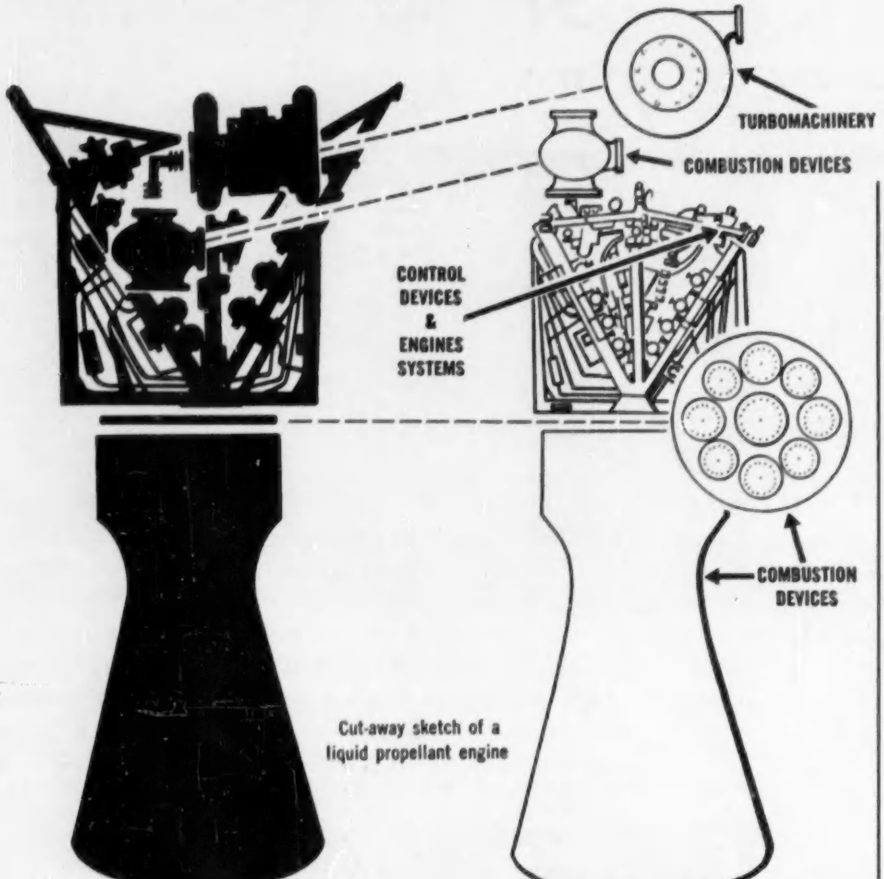
Circle No. 31 on reply card



PLUG-IN PHOTORELAY

Utilizing a broad area cadmium sulfide photocell and a Series 41 relay, both mounted on a plug-in base, this compact photorelay will operate at 5 foot-candles or less, and release at 0.1 foot-candle or more. Supply voltage is 115 vac, and temperature range is minus 40 to plus 75 deg. C. At present, the unit is being considered for such applications as furnace flame-out control, elevators, conveyors, weighing equipment, and other machinery. Housing measures only 1½ in. sq by 2¼ in. high.—Sigma Instruments, Inc., Boston, Mass.

Circle No. 32 on reply card



Cut-away sketch of a liquid propellant engine

R & D Engineers: can you fit into this picture?

Chances are that one of the areas of engineering listed at the right will fit you like a glove! All you need be is a research, development or design engineer with a desire for challenging work and pertinent background experience.

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Power distribution, unit substations, switch-gear, protective devices, control circuits, and relay circuits.

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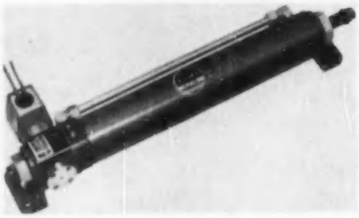
NEW PRODUCTS

FINAL CONTROL ELEMENTS



NEW VALVE-IN-HEAD

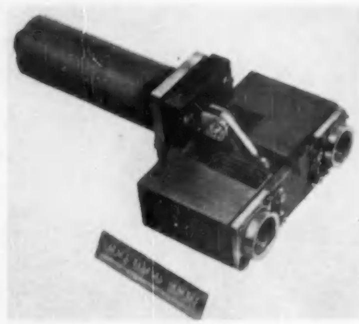
The new air cylinder shown here uses a single 110-volt, 60-cycle solenoid valve to control the movement of the cylinder rod when air is brought to a single port on the unit. When the solenoid is energized, the rod goes forward and stays. Breaking the electrical contact returns the rod to its original position. The cylinder will operate on air pressures of 5 to 150 psi. The solenoid itself is said to be silent in operation.–A. K. Allen Co., Brooklyn, N. Y.

Circle No. **33** on reply card

METERING VALVE

Only 24 in.-lb of torque is required to operate this valve at 6,000-psi line pressure. A leakproof seal is obtained by means of teflon, nylon, or formica seats, and an O-ring spindle seal. Over-torquing cannot damage the seat or needle, as the buffer plate and metering pin act as a forming die. The unit can be completely overhauled in minutes without disturbing the piping or mounting.–Robbins Aviation, Los Angeles, Calif.

Circle No. **34** on reply card



PROPELLANT VALVE

Shown is one of a new series of pressure operated, multi-line propellant valves now in production. Valves are said to have zero leakage when closed and a zero relative pressure drop when open. The linked multi-line design provides two-line or three-line control functions for any line-size combinations from ½ in. to 4 in. The piston-type actuator will accept gas or liquid at from 200 to 3,000 psi. Propellant pressures can range from 0 to 1,500 psi. Operating temperature range is from minus 320 deg F to plus 350 deg F. Valve will handle a variety of fuels and oxidizers, including liquid oxygen, JP-4, JP-5, helium, fuming nitric acids, hydrazine, aniline, ethylene oxide, etc.—Hydromatics, Inc., Cedar Grove, N. J.

Circle No. 35 on reply card

FLEXIBLE SOLENOID

Designed for guided missile systems and adaptable to industrial automation, this new line of lightweight solenoid valves features flexibility. It can be operated from the open or closed position, the conversion being made by a simple rearrangement of the solenoid. The hermetically sealed solenoid can also be rotated on the valve body to place the electrical con-

nector in the most desirable position. The whole unit measures only 2 in. in length by 1 in. in diam at the solenoid end. Applications are the control of air, helium, nitrogen, liquid oxygen, and corrosive liquids. Zero leakage is the result of an internal vent to the atmosphere through a controlled outlet. This is said to prevent moisture laden air from reaching moving parts.—Clary Corp., San Gabriel, Calif.

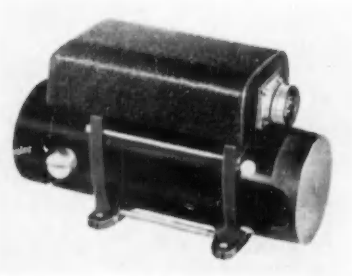
Circle No. 36 on reply card

SPACE SAVERS

A complete line of manifold mount control valves in two-, three-, four-, and five-way types is now available with sizes ranging from ⅛ in. to 1 in. NPT. Units are designed for installations where space and speed of removal are important considerations. The manifold plate and piping are installed first. The valve proper is then bolted to the manifold plate. It is completely independent of the piping and can be readily removed or replaced in a minimum of time. Valves are available with any type of actuating device, and for pressures from partial vacuum to 500 psi. —Versa Products Co., Inc., Brooklyn, N. Y.

Circle No. 37 on reply card

COMPONENT PARTS

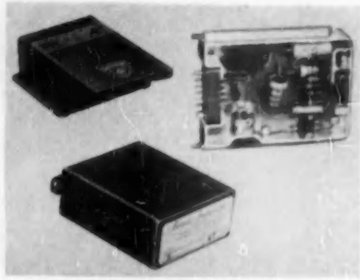


EFFICIENT LIGHTWEIGHT

Said to produce unusually high wattage per pound of weight and per cubic inch of volume, this closely regulated inverter takes an input of 24 to 30 vdc at 4.5 amp max, and has an output of 115 volts, 440 cycles, one-, two-, or three-phase, 20 to 40 watts. The complete unit, inverter and radio noise filter, weighs only 3¾ lb. Efficiency is said to be 40 percent at room ambient and 25-volt input.—John Oster Mfg. Co., Racine, Wis.

Circle No. 38 on reply card

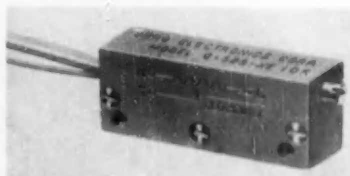
NEW PRODUCTS



SERVO AMPLIFIERS

A new series of subminiature servo amplifiers is available in both transistor and vacuum-tube types. Designed for use with 400-cps servo motors in airborne service, they vary in size from 6 to 12 cu in. and weigh from 4 to 5 oz. Transistor models include 1-watt and 3-watt units with silicon transistors capable of withstanding a wide range of environmental conditions. Using germanium transistors, 6-watt and 9-watt units provide high power output at low cost. Other transistor amplifiers include resolvers, summing automatic gain control, and demodulator units. A vacuum-tube precision summing model handles seven inputs, is accurate to within 0.05 percent, weighs only 4 oz, and occupies 4 cu in.—W. L. Maxson Corp., Long Island City, N. Y.

Circle No. 39 on reply card



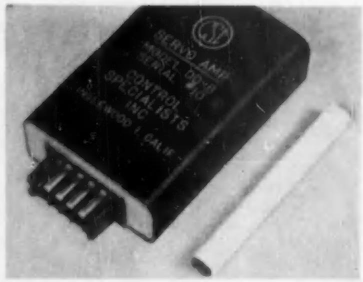
RUGGED TRIMMER POTS

The miniature trimming potentiometer, shown here actual size, features rugged construction, stability, and long life. Unit is adjustable through 32 turns of a precision threaded shaft. Because the wiper is supported on two sides, settings are stable under extreme vibration, shock, and acceleration. Resistances range from 100 to 50,000 ohms in one case size. Linearity is within 1 percent; resolution, depending on the resistance, varies from 0.2 to 2.0 percent. Units are available with insulated leads, plug-in terminals, or solder lugs.—Aero Electronics, Gardena, Calif.

Circle No. 40 on reply card

DOUGLAS ROESCH

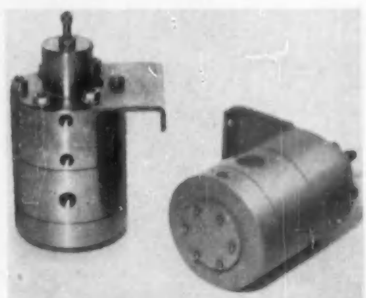
NEW PRODUCTS



FULLY PACKED

This new transistorized electrohydraulic-valve amplifier delivers an 8-ma differential current to a 2,000-ohm center-tapped load. It has a 60-db power gain, and shows no reduction in performance at temperatures as high as 170 deg F. The unit can be used with either 60- or 400-cycle excitation. Variable gain, balance, and quiescent controls are housed in the compact 1-in. by 2-in. by 3-in. envelope. – Control Specialists, Inc., Inglewood, Calif.

Circle No. 41 on reply card



VAPORIZER REGULATOR

Designed originally for use with infrared analyzers and refractometers, this new vapor regulator can be used in a number of other continuous sample systems. It assures vaporization and permits pressure control of the liquid samples introduced. Measuring 3⅜ in. in diam. by 6¼ in. high, the regulator will handle inlet pressures up to 150 psi. Outlet pressures may be regulated from 0 to 50 psi, constant within 0.1 psi when upstream variations do not exceed 10 psi. Maximum steam pressure is 50 psig and maximum heater output, when heating element is used instead of steam, is 75 watts.–Consolidated Electrodynamics Corp., Pasadena, Calif.

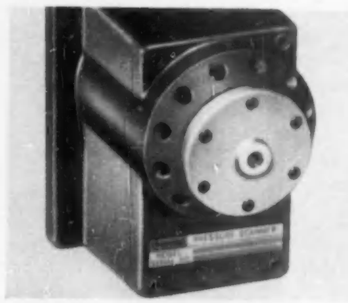
Circle No. 42 on reply card

NEW PRODUCTS

NEW MODEL CHARACTRON

Only 7 in. in diam, this new Charactron Shaped-Beam Tube still reproduces 1,200,000 tiny letters and numbers per minute. It has nine times the information density (characters per square inch) of the earlier direct reading models. The tube is designed for use with photo-recording devices in an electronic computer readout system. Each character is reduced to a height of 0.035 in. and 10,000 can be reproduced for photographing in one frame. Characters appear on a screen $4\frac{1}{4}$ in. square within a 6-in. circle. Overall length of the tube is 40 in.—Stromberg-Carlson, San Diego, Calif.

Circle No. 43 on reply card



SCANS A DOZEN POINTS

Designed to enable the measurement of up to 12 pressure sources with only one transducer, this new pressure scanner can also be used to reduce error by automatically introducing a calibration pressure during each scan cycle. The transducer is vented to atmosphere between ports, thus eliminating hysteresis effects. Internal rotor is driven by a unidirectional high-torque motor. A relay circuit provides dynamic braking for accurate port registration. By using one unit to interrogate 12 others, it is possible to measure 144 pressures. Unit will operate over a range of from 0.1 to 350 psi with dry air and noncorrosive dry

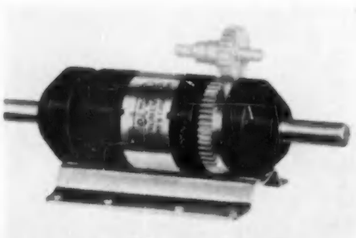
gases. Its low internal volume prevents any adverse effects on the pneumatic response of conventional pressure systems.—G. M. Giannini & Co., Inc., Monrovia, Calif.

Circle No. 44 on reply card

NEW FRICTION CLUTCH

The magnetic-type friction clutch shown here is designed for applications in low-power servomechanisms, and meets tough military environmental and performance specs. Standard models operate on 24 vdc, delivering a minimum of 50 oz-in. torque. Response time is within 3 millisec, power consumption is 3 watts, and the maximum error upon engagement is 2 min of arc. Tests reveal no performance drop at rated load and high speed for one million cycles.—Dynamic Instrument Corp., Westbury, N. Y.

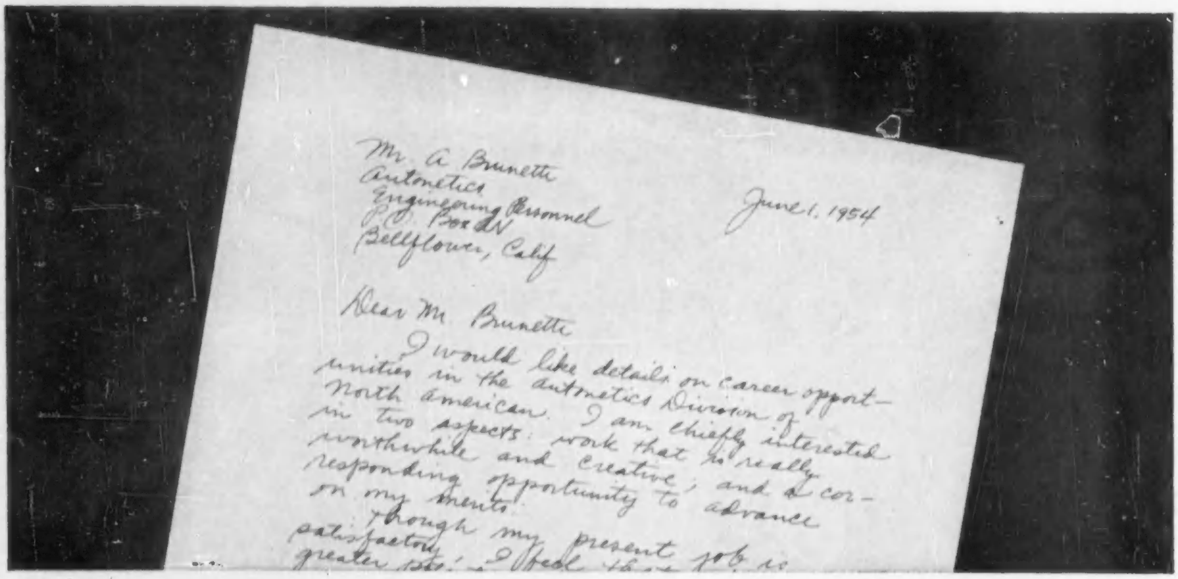
Circle No. 45 on reply card



THIRTY-FOUR RATIOS

A new line of miniature differentials is now available for applications where small size and long life are essential. Ball bearing shaft supports are foot-mounted for easier installation. The units will add or subtract two rotating inputs, and can be used for controlling relative speeds or for changing speeds quickly without disconnecting the power source. Thirty-four speed ratios, from 1:1 to 27:1, provide wide design possibilities. An optional anti-backlash feature is the result of using two parallel gear trains spring loaded against each other.—Metron Instrument Co., Denver, Colo.

Circle No. 46 on reply card



Mr. A. Brunetti
Autonetics
Engineering Personnel
P.O. Box AN
Bellflower, Calif

June 1, 1954

Dear Mr Brunetti

I would like details on career opportunities in the automatics Division of North American. I am chiefly interested in two aspects: work that is really worthwhile and creative; and a corresponding opportunity to advance on my merits.

Though my present job is satisfactory

This letter moved a man ahead 5 years

Two years ago a man took 10 minutes to write this letter. Today he enjoys the responsibility and professional standing in the AUTONETICS Division of North American that might have taken 7 to 10 years to achieve in other fields.

THE FIELD AT AUTONETICS—A FIELD OF OPPORTUNITY

Now under way at AUTONETICS are nearly 100 projects, comprising some of the most advanced and progressive work being done today in the fields of Electronics, Electro-Mechanics, Control Engineering and Data Processing.

You will work on automatic control systems of many kinds, for manned and unmanned vehicles. Every state of the art is represented, from preliminary conception right through flight testing. Facilities are the finest obtainable. Your colleagues will be men of ability and imagination, of the highest professional standing.

The long-range potential in this field is truly limitless. The techniques being developed at AUTONETICS today will have the widest application in the industrial methods of tomorrow.

You owe it to yourself to consider how far you can advance by entering this exceptionally promising field right now. Here are the opportunities:

COMPUTER SPECIALISTS • COMPUTER APPLICATION ENGINEERS • ELECTRO-MECHANICAL DESIGNERS • ENVIRONMENTAL TEST ENGINEERS • ELECTRONIC COMPONENT EVALUATORS • INSTRUMENTATION ENGINEERS • FIRE CONTROL SYSTEMS ENGINEERS • FLIGHT CONTROL SYSTEMS ENGINEERS • ELECTRONIC RESEARCH SPECIALISTS • AUTOMATIC CONTROLS ENGINEERS • ELECTRONIC ENGINEERING WRITERS • INERTIAL INSTRUMENT DEVELOPMENT ENGINEERS • PRELIMINARY ANALYSIS AND DESIGN ENGINEERS • RELIABILITY SPECIALIST

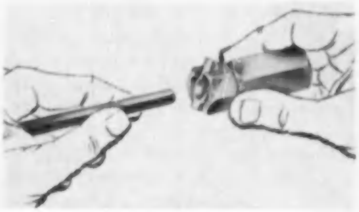
Write your letter today. Decide now to get the facts, so you can make the most of your potential. Just put your address and brief qualifications on paper—handwritten will be fine. Reply will be prompt, factual, confidential.

Write: Mr. A. Brunetti, Autonetics Engineering Personnel, Dept. 991-12-CON, P. O. Box AN, Bellflower, California

Autonetics
A DIVISION OF NORTH AMERICAN AVIATION, INC.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

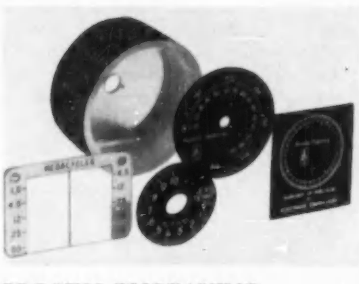
NEW PRODUCTS



NO TOOLS REQUIRED

This unusual tube connector should be ideal for applications involving pressure or vacuum testing. No tools, threading, or soldering is required. The connection is made by simply pushing the end of the tubing into the stop position. This operation automatically locks the tube in a leakproof seal, ready for vacuum exhausting or pressure filling. The connector is designed to operate at any pressure to 1,000 psi and any vacuum to 25 microns. For disengagements, the lever is simply pushed forward, and the tube pulled out. The connector is available in three standard sizes: for ¼ in., 5/16 in., and ⅜ in. OD tubing.—Mechanical Products Corp., Chicago, Ill.

Circle No. 47 on reply card



PROCESS ENGRAVING

Accuracy within 2 min of arc and concentricity within 0.005 in. total indicated runout are claimed by the manufacturer of these precision instrument dials. To achieve such accuracy, a master is engraved on optical flat glass and reproduced photographically. After processing, no protective coating is required as the original finish is solvent resistant and exceptionally durable. Dials can be produced on aluminum, brass, steel, lamicoid, plexiglass, etc. Plastic parts can be opaqued, transparent, or translucent for back and edge lighting effects. — Ackerman Engravers, New York City.

Circle No. 48 on reply card

All Around the Business Loop (continued from p. 38)

and the reported vote increase was compatible with the increase in precincts reporting. NBC was confident that its transmission system would give it a 15- to 30-min jump on competitors in reporting the returns.

NBC's Studio 8H in New York received election returns from 45 states via Data Transceivers, and from Connecticut, New Jersey, and New York via the AP wire. All these returns were processed through a 650 for a validity check, and the following calculations were made: the percent of precincts reporting in each state; increase in precincts reporting; the leading party by state; national totals; increase in national totals, and the electoral college standings. At established intervals, the 650 read out the latest information and an IBM 402 prepared the official printed reports. No analytical-type calculations were prepared on the 650 at studio 8H. This operation was reserved for the network remote coverage locations.

Local programming throughout the country also made use of IBM machines, including the 702 and 705. Arrangements were made with **Teleregister Corp.** to build indicator boards to show the percent of precincts reporting the Democratic and Republican votes from each state, the national totals, and the electoral college standings. IBM built a special electric card reader which transmitted direct from the punch cards to the Teleregister boards, thus eliminating the possibility of human error.

CBS once again employed Remington Rand's giant Univac as a political prophet. This machine saw service in the presidential contest of 1952 and the congressional elections of 1954. Its early predictions in 1952 so startled the programmers that they tried to modify the setup, only to see the machine type out a complaint. Final tabulations confirmed its prediction of an Eisenhower landslide. In 1954, the electronic giant scored again when it predicted a Democratic sweep of both houses of Congress.

Dr. Max Woodbury, professor of mathematics at New York University, prepared the formulas on which the predictions were based, as he did in 1952 and 1954. These formulas were based on outcomes of previous elections, which were seen to conform to certain patterns within the limits of statistical error. For example, in 1944 and 1948, the first 25 percent of the precincts reporting in a certain state accounted for 30 percent of the total Democratic vote and 20 percent of the total Republican vote. Univac, in making the predictions, assumed that patterns such as these would hold true. Similar patterns allowed Univac to translate the early returns from some states to final vote predictions for the others. The complicated statistical computations finally resulted in prediction of the number of electoral votes, the number of House and Senate seats, and the number of votes (or seats, as the case may be), which were reasonably certain for each party, and in a measure of how accurate the predictions were. Univac also kept its eye on incumbents who seemed to be losing, and on any particular deviations from expected outcomes. (In 1954 Univac consistently maintained that Senator Clifford Case of New Jersey had a good chance, even after he conceded. He won.

Among the inherent problems of

Research and development center for AMF in Stamford: strictly a home for ideas.

this type of forecasting, said Woodbury, are the bias of early returns in some states where Democratic votes always come in early; the effect of special or new issues before the voters; and the effect of early returns which are reported late. Attempt is made to solve these problems, he said, by identifying and measuring the biases and the uncertainties. "The best guess of the outcome can be done in 2 min," Woodbury said, "but the big problem is to decide the soundness and accuracy of the prediction." The entire time for one operation—from data input to printed result—is about 6 min, and this includes the solution of a 531-term polynominal.

It has been estimated that in six hours on election night the Univac, now located in N. Y., did 1,800 hours of pencil and paper work.

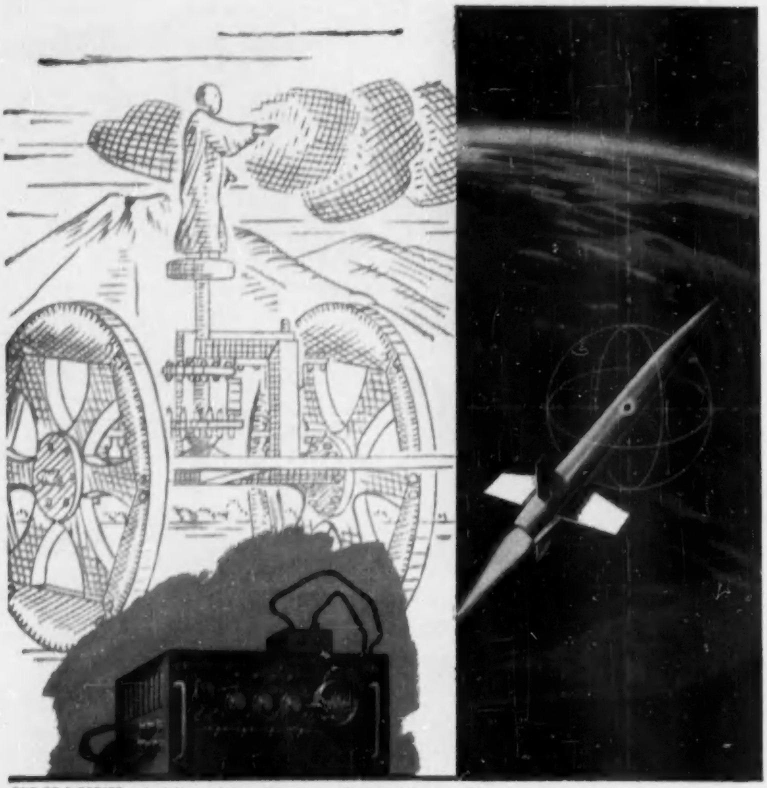
Elecom 125, Underwood's new medium-scale electronic computer, made its first public appearance on election night, when it computed returns and predicted the presidential contest state by state and for the nation. ABC-TV, as part of its election coverage, featured visits by remote telecast every half hour to Underwood's new **Data Processing Center** where Elecom 125 was operating. Returns received at the ABC studios were teletyped to the center and transcribed onto the computer's punched-paper-tape input. As the results were calculated, Elecom 125 automatically typed them out in jumbo-sized type on a specially prepared typewriter. An ABC-TV camera, trained on this typewriter, transmitted the typed results directly to home TV screens.

The Elecom 125 system, consisting of a general-purpose electronic computer and an automatic data-handling unit (the File Processor), is completely decimal in operation and handles alphabetic and alphanumeric data. It was designed for general business rather than scientific applications, and is capable of performing any mathematical computation that can be set up. The system differs from the giant electronic brains in that it has a medium (millisecond) rather than a microsecond speed. (Since the computer's magnetic drum memory was sufficient to hold all the necessary historical data, the File Processor was not required for the election night operation.)

Data on presidential elections of the last four decades, gathered from many sources, were selected and programmed into the machine by Dr. Leon Nemerever, of Underwood's **Electronic Computer Div.**, and his staff. Underwood retained Louis Bean, a political analyst who accurately predicted the 1948 presidential election, as a consultant in the operation. Bean selected the data and developed the intricate correlations between county and state, between states, and between state and nation, upon which equations relating the interplay of political behavior were built. These equations, fed into Elecom 125, formed the basis for the predictions. Provisions were made for automatic strengthening or softening of predictions as returns increased and trends became apparent. Also programmed in were messages such as "I'm getting excited" and "I goofed", which were to be printed out if the race became close or if a radical change in the predictions occurred.

▶ **Teleregister Corp.**, which has made a name for itself as a maker of special-purpose electronic systems for business and industry, has perfected a coast-to-coast automatic flight reservation system for **Trans World Airlines.** Called Magnetronic Reservisor, the system expands on Teleregister's Reservisors now used in large cities by most other airlines. By means of

Bailey Meter Co. builds in Wickliffe, O.: working space here climbs to 165,000 sq ft.



magnetic-drum storage and electronic transmission, the new Reservisor gives an agent all the information he needs for servicing customers located anywhere along TWA's 35,000 miles of routes on four continents. Data are stored in "brain centers" in three cities, New York, Chicago, and Los Angeles. Once he has contacted a brain center, though his "agent set", which looks like a small adding machine, an agent can send and receive all information channeled by the smaller Reservisors, plus one thing more: wait-list requirements, which, transmitted to the TWA central office, take the place of the big boards currently used to post availability of flight space. Installation of the new equipment is expected to be completed next fall.

▶ A new Waltham, Mass, electronics firm, **Neutronics Research Co.,** will do research and development work in countermeasures, communications, medical instruments, educational devices, and control circuits. Partners in the enterprise are Harry Stockman, H. Philip Honanian, and E. James Johnston.

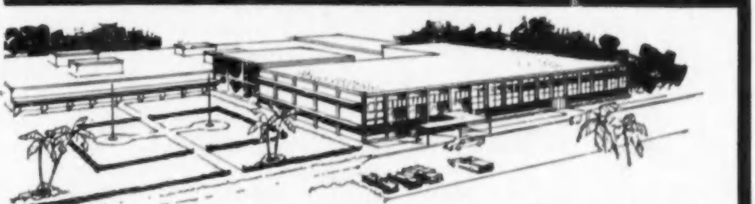
▶ **Servomechanisms, Inc.,** has moved its corporate offices to New York City to give better service to its increasing accounts there and to provide more elbow room for production activities at Westbury, N. Y., where the corporate offices had been located. The new quarters, at 445 Park Ave., add 3,000 sq ft of space to Servomechanism's working area. Just prior to this move, the company leased 17,000 sq ft in Garden City for its growing **Eastern Div.**

Companies A-Building

▶ A two-story addition (72,000 sq ft) to **Bailey Meter Co.**'s plant in Wickliffe, Ohio, bringing space in Wickliffe to 165,000 sq. ft.

▶ An industrial science center (158,000 sq ft) recently opened in Morton Grove, Ill., near Chicago, by **Cooke Electric Co.** The **Cooke Technological Center,** as it is called, consists of seven one-story buildings, a heliport, and parking facilities for 1,200 cars. First to occupy the site were advance teams of **Cooke Research Laboratories** and **Inland Testing Laboratories,** two of the company's seven divisions.

▶ A research and development center (200,000 sq ft) in Stamford, Conn., for **American Machine & Foundry's Central Engineering Laboratories.** Included in the $4-million project will be five laboratories and an administra-



Honeywell's new facility in St. Petersburg, Florida will be the first of its kind ever built in this country exclusively for the design and development of inertial guidance systems.

HONEYWELL GOES TO FLORIDA:

200 OUTSTANDING SCIENTISTS AND ENGINEERS ARE NEEDED FOR HONEYWELL'S NEW INERTIAL GUIDANCE PROGRAM!

Right now Honeywell is selecting, for the engineering staff of its new Florida facility, creative, forward-looking men with the scientific knowledge and ability to qualify for this advanced work.

These men will receive first-rate salaries, have unusual opportunities for advancement and be supplied with the finest in equipment and facilities. They will work in small design and development groups where individual ability and contributions are quickly recognized and rewarded.

This Florida location affords ideal living. Nearby St. Petersburg has many cultural and educational advantages, and the entire area is noted for its climate and recreational facilities. Housing is plentiful, cost-of-living lower than the national average.

MINNEAPOLIS **Honeywell**

H Aeronautical Division

Immediate Design and Development Openings in Inertial Guidance:

Systems Analysts • Product Designers • Product Managers

Special Needs for Trained Personnel in the Following or Related Fields:

Inertial Guidance	Digital Computers
Systems Engineering	Computer Logic
Mathematical Analysis	Mathematical Analysis and Programming
Platform Design	Transistor Pulse Circuitry
Floated Gyro and Accelerometer Design	Magnetic Memory Design
Precision Analog Computer Design	Panel Instrument Design
Transistor and Magnetic Circuits	Electronic Packaging

Optic and Ground Handling Equipment

SEND RÉSUMÉ TODAY if your interests and experience are related to the fields listed above. Mail immediately a résumé of your education and experience to Bruce D. Wood, Technical Director, Dept. TF-2, 1433 Stinson Blvd., N.E., Minneapolis 13, Minnesota.

tion building, each with its own conference rooms and engineering areas. No manufacturing will be done on the 39½-acre site; instead, the emphasis will be on design and development. Stamford was chosen for the center after a thorough study of various locations in Pennsylvania, New York, and New Jersey, as well as Connecticut.

Important Moves by Key People

► As chief scientist of the Office of Naval Research, **Emanuel R. Piore** held the top civilian post in that organization. It was partly through his efforts that ONR became the leading research arm of the government, taking a leading role in the use of general-purpose digital computers and in development of programs in applied mathematics and numerical analysis. Now, as director of research for IBM, Piore takes on duties whose scope is at least equally wide. The specialist in solid-state and surface physics will head a company-wide study project that is making use of laboratories in New York, California, and Zurich, Switzerland. Most recently research vice-president of Avco Mfg. Corp., which he will continue to serve as consultant, he has also been with RCA and CBS-TV, and is associated with some of the early work in color television. He is a consultant for the Science Advisory Committee of the Office of Defense Mobilization and a fellow of the IRE.

► Electronic Control Systems, Inc., which apparently has decided to call a spade a spade when it comes to bestowing titles on its key executives, has dubbed **Jack Rosenberg** manager of automation. If this is a precedent, it is about time it was set. Breaking this particular chunk of ice has taken a long time, during which many companies that never hesitated to use "automation" in their press releases might have done a lot of needless beating about the bush to avoid using the word in executive titles. Rosenberg, who will be in charge of design, development, and prototype construction of high-speed special purpose digital computers and machine-tool controls, has had experience at Princeton University, where he steered the instrumentation phase of a medium-sized synchro-cyclotron, and worked under John von Neumann on the prototype Maniac computer. He came to the Stromberg-Carlson affiliate from GE's Electronics Laboratory in 1954.

► **Bernard Salzberg,** who for 15 years was associate superintendent of the Electronics Div. of the Naval Research **Laboratory,** has been named chief scientist of the Research & Engineering Div. of Airborne Instruments Laboratory, Inc. Salzberg's work in the

E. R. Piore

Jack Rosenberg

Bernard Salzberg

A. J. Hanssen

Z. R. Smith

B. R. Teree

are you killing that still, small voice?

When that voice prods your professional ego with, "You can do bigger and better things!," do you smother it with a wet blanket of doubt?

And when that same voice whispers to you of a gentle climate where the snow is yours just for the asking and sunshine is always yours for the basking, do you clobber it with the sledge hammer of self-denial?

Don't kill that voice! Its wisdom could lead you to a place where you'll find those bigger things, that better life—Firestone. If you've a mind that can matter in the guided missile field, Firestone needs you in its vital development program for the Army's "Corporal," first surface-to-surface guided ballistic missile. Here are just a few of our needs:

Flight Simulation
Electronics Systems
Missile Component Design
Systems Analysis
Structural Design
Field Engineering

Next time you hear that still, small voice, don't reach for your shotgun. Reach for your pen. Write—right now! Let that still, small voice guide you to big accomplishment for you, big happiness for your family!

Firestone

GUIDED MISSILE DIVISION

RESEARCH • DEVELOPMENT • MANUFACTURE

"Find your Future at Firestone"—Los Angeles • Monterey

WRITE: SCIENTIFIC STAFF DIRECTOR, LOS ANGELES 54, CALIF.

high-frequency Acorn tubes, in shaped grids and anodes for conventional receiving tubes, and in other phases of electron tube development has brought him such honors as the NAM's Modern Pioneer Award, the IRE's Harry Diamond Award, and Polytechnic Institute's Certificate of Distinction.

▶ **Albert J. Hanssen,** who has been chief engineer of Black, Sivalls & Bryson, and chief engineer of McAlear Mfg. Co. of Chicago, joins Conoflow Corp. in an identical capacity. He will work under Vice-president Warren H. Brand, supervising the administrative and design functions of the company's Engineering Dept.

▶ Potter & Brumfield, Inc., also has a new chief engineer. He is **Zeke R. Smith,** who joined the company three years ago in Chicago. His former affiliations include Bendix Aviation Corp., Airborne Instrument Laboratory, Wilcox Electric Co., and Vendo, Inc.

▶ This seems to be the month for chief engineers. Greer Hydraulics' new man is **Baboo Ram Teree,** an authority on aircraft and industrial hydraulics. A director of the National Fluid Power Association and an associate fellow of the Institute of Aeronautical Sciences and the Royal Aeronautical Society, Teree has been with The Weatherhead Co. of Cleveland, Ohio (chief engineer of two divisions, project engineer in charge of development of aircraft equipment, director of the Weatherhead Laboratories), New York Air Brake Co. (director of engineering of the Hydraulic Div.), and Curtiss-Wright Corp. (hydraulic group engineer). Another change at Greer spotlights **Jules Kendall,** named vice-president in charge of the company's new R&D Div., which will specialize in jet airliner airframes, engines, missiles, etc., on a systems basis. Kendall, with Greer since 1945, most recently was vice-president in charge of sales.

▶ **John J. Burke** goes from the government's Jet Propulsion Laboratory, where he was head of the Guidance & Electronics Div., to Hallamore Electronics Co., which has named him vice-president for engineering. While at the Jet Propulsion Lab Burke made some major contributions to the Army's Corporal missile. Before that he worked on missiles and aircraft controls as a member of Hughes Aircraft Co.'s research staff.

▶ In response to requests for broader applications of the Tipp-Tronic safety controller for conveyor systems, Tipp Mfg. Co. has established a new Controls Div., which will manufacture and distribute industrial control packages. Chief engineer of the division is **R. A. Moenich,** who has done design and development work in centralized controls for railroads and telephones. **David J. Dolan** hires on to handle field sales problems involving the new line.

▶ Key missile men appointed recently by important control makers include **Kirke W. Marsh,** general manager on a major missile project assigned to the Pacific Div. of Bendix Aviation Corp., and **Arthur N. Corner** and **Upton S. Brady Jr.,** project managers for missile test equipment and missile guidance equipment, respectively, at Farnsworth Electronics Div. of International Telephone & Telegraph Corp. Marsh comes to the Pacific Div. from Bendix's Research Laboratories in Detroit, where he had been located since he joined the company last February. Before that he was with Fairchild Guided Missiles (senior project engineer), Hazeltine Electronics Corp., and Airadio, Inc. Corner, most recently assistant to the president and acting director of engineering of Electronics Corp. of America, has also been with Melpar, Inc., The Kellex Corp., Link Aviation, Inc., The Glenn L. Martin Co., and McDonnell Aircraft Corp. Brady, a retired Navy captain, was formerly program director for guided missiles in the Navy Dept.'s Bureau of Ordnance.


J. J. Burke


R. A. Moenich


K. W. Marsh

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(100) MULTI-STAGE METERS. Fischer & Porter Co., Flowmeter Div. Catalog 10-A-34, 10 pp. Presents an introduction to the F & P multi-stage "Flowrator" meters, describes components involved, and gives useful data on sizing floats for various applications.

(101) RADIATION PYROMETERS. Minneapolis-Honeywell Regulator Co., Industrial Div. Catalog C 93-1, 24 pp. Describes complete line of Brown Radiamatic pyrometers, including the new sapphire rod model developed primarily for use in seed crystal growing. First page describes theory and principle of radiation pyrometry.

(102) PNEUMATIC CONTROLLERS. The Bristol Co. Bulletin A-130, 56 pp. Gives complete details on a new series of pneumatic controllers. Sections describe control principles and illustrate the various control modes available.

(103) JET ENGINE HARNESS. Fenwal, Inc. Bulletin MC-141, 4 pp. A pictorial description of a unique semi-rigid harness and thermocouple detection system for jet engines. Includes data on the new button-terminal couples and various manufacturing details that eliminate contamination and provide resistance to vibration.

(104) BATCH CONTROL. Fischer & Porter Co. Bulletin 91-109, 4 pp. Describes F&P batch-control systems for automatically adding a predetermined volume of fluid to a batch process. Includes complete specifications on the components and on the accuracy of the combined system.

(105) BALL BEARINGS. The Barden Corp. General Catalog, 64 pp. This catalog was actually prepared after a survey to determine the kind of material bearing users wanted and the form in which it would be most useful. Contains a dimensional index, a series index, and a visual guide to bearings.

(106) ANNUNCIATOR SYSTEMS. Panellit, Inc., Panalarm Div. Catalog 100B, 32 pp. Contains information on the function and general features of Panalarm Annunciator Systems. Operating sequences, mechanical specifications, technical data, and performance described.

(107 PHOTOELECTRIC CONTROLS. Autotron, Inc. Catalog 57, 16 pp. Describes equipment and illustrates numerous applications in industrial control. Prices are included with the descriptions.

(108) PROCESS CONTROL. Leeds & Northrup Co. Brochure, 12 pp. Presents all L&N instruments for chemical-process applications. Covers loggers, scanners, recorders, various process gas analyzers, and complete control systems.

(109) DATA PROCESSING. DITTO, Inc. Booklet, 24 pp. "Integrated Data Processing: A Factual Analysis" tells how to select the proper data processing system for specific needs. Discusses one-writing systems, punched cards, tapes, transmission, and computer types.

(110) STURDY ROTAMETERS. Schutte & Koerting Co. Bulletin 18RG, 12 pp. Illustrates line of Series 18200 variable-area-type rotameters. Also gives detailed data on application, construction, operation, and installation.

(111) ELECOM 125. Underwood Corp., Electronic Computer Div. Data sheet describes Underwood's Elecom 125 Business Data Processing System, covering the latest additional features. Lists operating characteristics of the computer as modified.

(112) FRACTIONAL HP MOTORS. R. A. Boehm Co. Introduces reader to the types and sizes of fractional hp motors available from this manufacturer. Suggests a number of possible applications.

(113) COOLING EFFECT DETEC-

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TOR. Fenwal, Inc. Bulletin MC-142. Describes a detector for protecting airborne electronic equipment against inadequate cooling conditions. Physical and performance specs are given, along with a description of the operating principle.
(114) CONTROL VALVES. Conoflow Corp. Bulletin LB-2, 12 pp. Gives details on construction and operating characteristics of company's LB control valves. Contains useful data on valve sizing for liquid, gas, and steam flow.
(115) VIBRATION EQUIPMENT. MB Mfg. Co. Bulletin 124E, 12 pp. Vibration pickups and meters, for use in vibration analysis work, are described. Detailed table gives data on natural frequency, damping, sensitivity, suspension, etc.
(116) CIRCUIT BREAKERS. Heinemann Electric Co. Bulletin 3411, 20 pp. Covers general purpose circuit breakers, detailing their hydraulic-magnetic principle. Design, operation, and applications described. Schematics, time-delay curves, and other useful engineering data included.
(117) PROPORTIONING PUMPS. Hills-McCanna Co. Catalog 602, 8 pp. Covers details and specifications of the Model "U" and "K" mechanical and hydraulic drive metering and proportioning pumps. Capacity-pressure charts included to simplify pump sizing.
(118) ACCURATE METERS. Greibach Instruments Corp. Catalog, 8 pp. Contains information on the company's unique meter movement and the light beam pointer that eliminates parallax. Charts and diagrams describe scales and ranges.
(119) INFRARED ANALYZERS. Leeds & Northrup Co. Folder N-91-620(1), 8 pp. Discusses the application of L&N infrared equipment to the monitoring of furnace atmospheres. Illustrations of typical chart records are included along with schematic diagrams of typical applications.
(120) DIGITAL PRINTERS. Victor Adding Machine Co. Bulletin, 12 pp. Contains some useful engineering data on Victor's high-speed serial and parallel entry digital printers. Covers operating specifications and provides details on calculating and printing techniques.
(121) MIDGET CONTROLS, Fenwal, Inc. Brochure MC-132, 6 pp. Describes complete line of miniaturized temperature controls for aircraft, airborne equipment, and related applications where space and weight are critical. Two types of midget thermoswitch units, and a variety of circular and rectangular thermostatic units are illustrated.
(122) BANTAM SPEED REDUCERS. Metron Instrument Co. Bulletin 98, 4 pp. Contains descriptive information on small but powerful speed reducers. Shows a number of applications, and lists significant features common to all units. Selection chart is included on back cover.
(123) TRANSMISSIONS & CLUTCHES. Salsbury Corp. Bulletin 56-D-1, 4 pp. Illustrates and briefly describes a line of automatic clutches and transmissions presently offered. Serves as a quick reference sheet when selecting such equipment.
(124) COMPANY FACILITIES. Servo Corp. of America. Brochure, 4 pp. "Research and Engineering" describes the company's facilities for research and development in infrared, electromechanical, optical, communication, control, and data-systems engineering.
(125) DC POWER SUPPLIES. Sola Electric Co. Bulletin DC-245, 4 pp. Gives pertinent technical data on six new adjustable-output, constant-voltage dc power supplies. Design features and applications briefly discussed.
(126) PRECISION INSTRUMENTS. Radio Corp. of America. Two-color folder illustrates and describes a number of precision instruments for use in measurement and control. Includes signal generators, pulse generators, multimeters, voltmeters, and impedance bridges.
(127) "THERMOSWITCH" CONTROLS. Fenwal, Inc. Folder, 6 pp. Contains physical specifications, performance data, ranges, and other information on Fenwal's differential expansion "Thermoswitch" units.
(128) PULSE TRANSFORMERS. Technitrol Engineering Co. Describes the application of pulse transformers to a variety of circuits. Covers a number of stock models, as well as custom-wound units for transistor, printed, and military circuits.
(129) RATE GYROS. Humphrey, Inc. Three single-sheet bulletins contain photos, descriptions, and general specifications for rate gyros, accelerometers, and potentiometers. Specs include data on weight, ranges, linearity, friction, hysteresis, resolution, natural frequency, etc.
(130) COMMUTATOR MAINTENANCE. Westinghouse Electric Corp. Booklet B-6150-A, 27 pp. "Carbon Brushes and Commutator Maintenance Team Up to Work for You" guides the maintenance man in solving his commutation problems. Sections deal with maintenance requirements, factors affecting commutation, and carbon brush materials.
(131) MAGNETIC MEMORIES. General Ceramics Corp. Technical Bulletin MM-1, 8 pp. Excellent description of the use of "Ferramic" materials in the operation of coincident current magnetic memories. Defines basic core requirements, discusses selection method in coincident current two-to-one selection memory system.
(132) CONNECTOR NEWS. Alden Products Co. Bulletin, 4 pp. "What's New at Alden's" describes a whole series of rugged high-voltage and multi-wire connectors, and the company's integrated component service.
(133) ENCAPSULATED RESISTORS.

Aerovox Corp., Cinema Engineering Div. Bulletin LC-1030BX, 20 pp. Includes first table to show equivalent military specifications. A line drawing accompanies each table of physical dimensions and electrical characteristics.

(134) SERVO ANALYZER. Servo Corp. of America. Brochure TDS 1100, 4 pp. Provides specs for four standard model servo analyzers. Contains a full page on how the instrument is used to solve various problems, and describes outstanding features of each model.

(135) PLASTIC TUBING. The U. S. Stoneware Co., Plastics & Synthetics Div. Bulletin T-97, 28 pp. Covers a number of flexible tubing formulations individually and in technical detail. Applications and limitations are presented along with physical properties and chemical resistances.

(136) HIGH PRECISION POTS. Electromath Corp. Technical Bulletins 63 and 64, 6 pp. total. Single turn, continuous rotation, high precision potentiometers are covered in Bulletin 64, while 3- and 10-turn, linear and nonlinear pots are handled in Bulletin 63. Complete specs are given, along with a list of possible modifications.

(137) RADIATION GAGES. Pratt & Whitney Co., Inc. Circular 600 9-56-5-CP, 12 pp. Describes the complete "RAD-I-ACC" line of x-ray and beta ray continuous, noncontacting, radiation gages. Discusses principle of operation, components, and the engineering data for each type.

(138) PNEUMATIC CONTROL. A. W. Cash Co. Bulletin 979, 4 pp. A new pneumatic recording controller and a pneumatic recorder are described. Data cover the models of control, ranges, chart sizes, appropriate primary elements, etc.

(139) VALVES. Aircraft Products Co. Bulletin 156, 72 pp. Presents the company's complete line of precision hydraulic and pneumatic components, including solenoid and manually operated selector valves, slide and poppet sequence valves, restrictor valves, and many other special parts for aircraft and general industrial use. Drawings, tables, and flow charts give construction and operating details.

(140) MACHINE CONTROL. Minneapolis Honeywell Regulator Co. Brochure describes Honeywell's electrohydraulic servo valve and new transistor servo amplifier. Includes detailed spec sheets and diagrams showing how the units combine for machine-control applications.

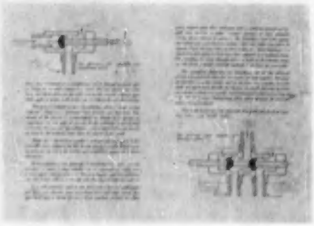
(141) VAPOR FRACTOMETER. Perkin-Elmer Corp. Brochure gives complete data on company's new model gas chromatography instrument, illustrating the performance characteristics of ten different liquid partition and solid adsorbtion columns it uses. Accessory equipment for sampling, etc., also described.

(142) DIAPHRAGM VALVES. Hills-McCanna Co. Catalog 100, 12 pp. Describes a new line of diaphragm valves in terms of applications, advantages, and specifications. Dimensional data given on three basic types. Plastic bodies and diaphragms also discussed.

(143) LITERATURE INDEX. Minneapolis Honeywell Regulator Co. Bulletin G-2, 20 pp. Covers catalogs, bulletins, and specification and data sheets on various products, and lectures and articles from Honeywell's "Instrumentation Magazine."

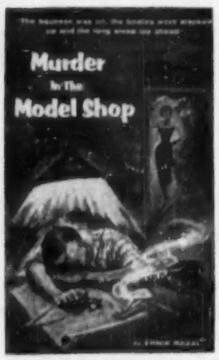
APPLICATION LITERATURE

(144) ALL ABOUT AIR VALVES. Mechanical Air Controls, Inc. Booklet, 30 pp. Written in easy-to-read, nontechnical language, this little booklet dsicusses the development of air valves in recent years, and the design contributions made by this company. Entitled



"The MAC Valve Story", it begins with a brief review of basic principles and a statement of the problems involved. Design of the form, structure, and action of the compact MAC valve is treated with equal clarity. This spread is from a section on the evolution of valving.

(145) A DESIGNER'S WHODUNIT. Servo Corp. of America. Pocket book (limited edition), 48 pp. "Murder in the Model Shop" is the most amusing piece of engineering literature that has come to this desk to-date. Written like a contemporary detective "thriller", the



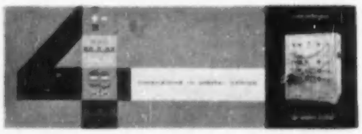
booklet is an account of how servo system and instrument problems were solved by use of Servo Corp.'s electromechanical assembly kits. Details on the numerous applications and advantages of these kits follow the conclusion of the story. Included also is a description of the Servoscope system analyzer for measuring gain and phase, lead or lag in the subsonic frequency range.

(146) REFERENCE DATA. American Machine & Foundry Co. Booklet, 20 pp. This handy, pocket-size "Electronics Facts Handbook" is a collection of carefully selected reference data that should prove useful to people concerned with government or industrial research and development activities. Typical among the subjects covered are navigation, guided

missiles, industrial electronics, digital and analog computers, AN nomenclature, and radar equipment. Last few pages relate some interesting facts about AM&F and

its facilities for development work. The inside back cover lists papers written by the electronics personnel.

(147) DIGITAL DESIGN. Burroughs Corp., Electronic Instruments Div. Booklet, 16 pp. The art of using digital techniques for testing, information handling, and control is the subject of this interesting booklet. Entitled "Four Dimensions in Digital Design—Pulse Techniques for Modern Control", the booklet



is basic enough to serve as an introduction to digital methods for those who wish to learn more about how to apply this art to their work. A clever series of die-cut pages illustrates graphically how a single combination of pulse control units can be rearranged in a number of ways to perform coding, simulation, arithmetic problems, etc.

(148) HIGH VACUUM SYSTEMS. Central Scientific Co. Bulletin 9, 24 pp. Provides an excellent guide for the laboratory planning of high vacuum systems. Prepared by experienced technicians, the booklet outlines in detail the correct

procedures involved and what equipment should be used for various vacuum system installations. It also contains charts showing capacity-pressure and speed-pressure curves for mechanical vacuum pumps. Photos of available pumps, along with descriptive material are also included.

ABSTRACTS

Papers from Stockholm

Abstracts of selected papers presented at the Instruments and Measurements Conference sponsored by the Royal Institute of Technology, Valhallavagen, Stockholm, Sept. 17-19, 1956.

Dr. A. J. Young (Imperial Chemical Industries, London) starts off the session on automatic process control with a review of the "progress of control development during the previous 30 years or so", noting that progress in this field is much slower than the growth in the development and use of servomechanisms. The first part of Dr. Young's paper treats the extent to which the main obstacles to continued growth have been removed. The remaining problems are not ones of lack of interest or lack of support, but rather are technical in nature. Future growth will be limited by a "still inadequate supply of economic, engineering and chemical data, and from the present inability to assess the economics of control system design."

Young discusses the trend toward use of the basic equations describing plant and process characteristics rather than the approximation method, and suggests "that the study of process economics, particularly from the control point of view, is really in its infancy . . ." He considers some of the possible changes that may be expected in application, particularly the "increase in the accuracy and speed of response of many types of measuring equipment."

W. F. Coxon (Electroflo Meters Ltd., London) presents aspects of the need for fundamental data, especially when converting a number of batch processes into a continuous process. He touches on these batch processes to illustrate the types of measurements and control problems that can arise:

1. The mixing of definite amounts of raw materials in a blending tank;
2. The flow of this blended material into a reactor for neutralization and ultimate separation of the product into two streams, (a) for purification, (b) for distillation;
3. The purification stage (a);
4. The distillation stage (b).

The author stresses the importance of selecting the appropriate measured value for control, and to locate the measuring points as close as possible to the source of disturbance. The role of the process "operative" is not neglected: Coxon emphasizes the importance of graphic panels for "seeing" the process, and the use of miniature recorders.

During the computer session, J. L. McPherson (U. S. Bureau of Census, Washington) reviewed factors limiting the use of electronics computing equipment. Says McPherson, in "Input and Output Problems in Mass Data Processing Applications of Electronic Computing Equipment", "the speed with which an electronic computer is capable of manipulating data can be practically lost for such applications as Census tabulation and commercial bookkeeping processes unless the input and output facilities associated with the computer can provide information for processing and take away the calculated results at speeds commensurate with the internal processing speed."

The relatively slow speeds of perforated tape and punched cards limit the computer, the author says, and "unless an electronic computer installation is equipped with magnetic tape or wire mechanisms it will not be capable of economically handling 'office work' kinds of application." A key punch operator can record about 50,000 characters per day, while computers read this at about 7,500 characters per sec. "Thus, the work it takes a key punch operator a full day to record can be read by the computer in less than 10 seconds."

One way the author hopes to improve the system's speed in processing data for the next Census is to use Fosdic, developed by NBS. It "uses a flying spot scanning principle to examine microfilm copies of forms filled out by our enumerators and to translate the intelligence recorded on the form directly to magnetic tape."

Output speed is somewhat better. Printing machines operated from magnetic tape present data of 100 characters per line at rates of 500 to 1,000 lines per minute. Sometimes the output can be printed in a format which minimizes the need for the computer to edit results.

C. S. G. Phillips (Oxford University, London) reported on "Gas Chromatography" during the session on physical methods for chemical analysis. He emphasizes the peculiar advantages and limitations of the gas chromatographic method and describes the method itself. Briefly, "The substances which are to be separated and analysed by gas chromatography are carried through the chromatographic column in the vapour state by means of a stream of an inert gas such as nitrogen. Their separate times of emergence at the outlet of the column are recorded automatically by means of vapour detectors. . . . The vapours are selectively retarded in their passage through the column by (absorption in) a fixed column liquid (gas-liquid chromatography) or adsorption on to a solid adsorbent (gas-solid chromatography). The record of the analysis appears as a series of peaks, each peak corresponding to the emergence of a particular substance which may be identified by its emergence (retention) time and its quantity estimated from the size of the peak." This analysis technique has found its greatest use in complicated mixtures, such as petroleum hydrocarbons, fatty acids, perfume materials, etc. The author hopes that in the near future chromatography will become as useful in identification as are refractive index and melting point.

Papers from Heidelberg

Abstracts from papers delivered at the VDI/VDE Conference, "Modern Theories in Control Engineering, and Their Usefulness," held at Heidelberg, Sept. 25-29, 1956.

Block-and Structure Diagrams for Network Analysis, E. Krochmann, Frankfurt.

Block diagrams show the actual circuit elements of a given control circuit; "structure diagrams" represent the describing system of equations by means of certain symbols; they are derived from the block diagram. Explanations of these symbols include nonlinear conditions. Rules are given for the transformation of the actual circuit into the "structure diagram". The usefulness of this kind of diagram is discussed with reference to the frequency response method, to successive integration, and to the treatment of a problem by means of the analog computer. Thus "structure diagrams" are means for the representation of circuits in general and particularly of control systems of any kind.

The Effect of Measuring Lags on Process Control Dynamics, D. W. Pessen and E. F. Hochschild, Minneapolis, Minn.

A relatively small lag in an individual component of a control loop, such as the measuring system, may often have a greater influence on the dynamic response of this loop than would be expected. The paper illus-

trates various methods of investigating this problem, among them: phase versus frequency plots, root loci, frequency response plots on the Nichols chart, and finally, the use of analog computers. A general view of the effect of measuring lags in proportional-action controllers is obtained by calculating and analyzing a number of systematically chosen examples.

On the Synthesis of Sampled-Data Systems for Open and Closed Loop Control, J. S. Cypkin, Moscow.

The sampled-data systems considered include: discontinuous control systems for technological applications, sample-data servomechanisms for the transmission of impulses and for use in radar systems, and control systems incorporating digital computers as control components. The relation between the transfer function, the frequency and time characteristics of the sampled-data system, and the discontinuous section on which the synthesis is based is indicated.

Stability Problems Encountered with the Application of Fast Pneumatic Control Components, H. Kaltenecker, Karlsruke, Germany.

Only fast control components are used in the pneumatic field today. Therefore, similar time elements may be present in large numbers. The danger of instability in a control loop increases with the number of its components and with the growing tendency of the time constants to become equal. Therefore, it must be tried to reduce the overall gain by means of a floating (not a constant) proportional-action of the transducers.

Self-Optimizing Systems, E. G. C. Burt, Farnborough, England.

The design of automatic control systems is usually influenced by the amount of noise associated with the true input. When signal and noise are stationary time series, the system which minimizes the mean square error can be determined using the methods of Wiener and others.

If the signal or noise spectral densities change with time, the form of the optimal system also varies. If, however, the fluctuations occur in the mean value, it is only necessary to adjust the system parameters for optimal state. In self-optimizing systems this is carried out automatically. To establish optimal conditions, some measure of the deviation from the optimum is required, and this is found by considering the error spectral density. An example of such a system is given and its stability discussed.

Automation, German View

AUTOMATION, MATERIALIEN ZUR BEURTEILUNG IHRER OEKONOMISCHEN UND SOZIALEN FOLGEN. *Friedrich Pollock. 318 pp. Published by Europaeische Verlagsanstalt GmbH, Frankfurt am Main, Germany.*

One may strongly disagree with the author as far as his conclusions are concerned, but it must be admitted that his book is a deep-searching, responsible one that treats the socio-economic problems of automation more thoroughly than any other book since Norbert Wiener's.

It is divided into two parts. The first part deals with the "History and the Economical and Social Problems of Automation Until the End of 1954". It contains most of the aspects of automation that the author is out to investigate. The second part, "Report on the Development of Automation During 1955", contains material that corroborates statements made in the first part. Some new thoughts are included.

Pollock essentially is making an analysis of the economic situation with respect to automation in the U.S., where automation already has taken effect and is more widely publicized than in any other country. From this point of departure, extrapolations can be made into the future and conclusions of general validity can be drawn.

Unemployment caused by automation is the central theme of investigation. Unemployment has become a much more explosive factor in our age than in any other. "As soon as unemployment rises in one of today's industrialized countries and exceeds a magnitude which is considered tolerable, intervention by the government becomes necessary unless it wants to endanger society itself" (page 49).

He discusses at length the article which Peter F. Drucker published in *Harper's Magazine* in March 1955 under the title "America's Next Twenty Years: I. The Coming Labor Shortage". Pollock refutes Drucker on various grounds and concludes that in reality we are menaced with large technological unemployment.

His statistics show that during the first half of this century (a) productivity per hour of labor doubled, (b) technological unemployment in many sectors resulted, (c) no structural unemployment was noticeable—in fact, between 1900 and 1953 the number employed in industry increased three times.

He seems to be rather hard put to show the great menace of unemployment in spite of these data, although his arguments are forceful. The high employment today is largely due to defense industries. On the basis of statistical considerations he arrives at an estimate of 10 million unemployed in 1964 in an economy without defense orders.

He quotes B. F. Fairless, board chairman of U. S. Steel, who states that the U. S. population increased by 22 percent between 1939 and 1953 but that the number of employed increased by 35 percent. Several reasons then are given why the period 1939-1953 should not have been used and why a comparison between 1946 and 1955 is more adequate. The increase in the number of employed (14.5 percent) in the latter period actually was slower than the increase in the population (17 percent).

Besides unemployment, there are two other main factors that concern the author, namely, the changes in the social structure and the effect of automation on small business.

He recognizes the leading part of engineers and the "hierarchy of managers that will determine the direction of enterprises" in automation. For all these, work will be interesting. For the rest, production will be boring. The skilled worker will lose out. "The danger exists that in view of the decreasing chances to utilize a better education in gainful employment, the stimulus to make the necessary personal and financial efforts will become weaker" (page 103).

The danger which automation spells for smaller enterprises is caused by

- increased self-financing (small business has not enough capital)
- advantages of automation for the decentralization of large enterprises while keeping centralized control
- the even greater stress on mass production
- the competition for engineering talent in which the larger companies offer greater fringe benefits and professionally more stimulating working conditions (??)

He refutes those who believe that the gradual development of automation will allow an adjustment with minimum disturbance. The average annual increase of productivity was 2 percent between 1930 and 1945. It increased to 4 percent in 1954. These and other data should "make those reflect who expect a gradual introduction of automation as a guarantee that it will not lead to abnormally large technological unemployment" (page 77). The year 1955 accelerated the development toward automation (even Russia created a new Ministry of Automatization). "The automatic production in U. S. gained probably more ground in 1955 than it did in the preceding five years" (page 189).

Some remedies are discussed, such as reduction of working hours without reduction in pay (the four-day week), public works, guaranteed employment plan, and increased unemployment insurance. A development toward a government-controlled capitalism appears to be unavoidable.

Pollock states that if the development of the second industrial revolution is left to a "free play of forces moderated merely by improvisations and palliatives, then destructive tendencies may develop to which no free society could offer resistance" (pages 89-90). He stresses "the basic fact that in principle only a planned economy can solve rationally the problems which arise because of automation" (page 289), since "the employment capacity of the American labor market depends to a large, though numerically hardly determinable extent on the continuation, if not expansion of public expenses" (pages 66-67).

W. G. Holzbock
Evanston, Ill.

Automation, British View

AUTOMATION: A REPORT ON THE TECHNICAL TRENDS AND THEIR IMPACT ON MANAGEMENT AND LABOUR, *issued by the Department of Scientific & Industrial Research. 106 pp. Published by H. M. Stationary Office, York House, Kingsway, London, W.C. 2, England. 6 shillings, 4.5 pence.*

This report was compiled by DSIR after "a study by its Intelligence Div. which is responsible for forward thinking on scientific and industrial problems. The object is to put automation in perspective and to give some idea of its probable future impact on industry. . . . It is emphasized that this report is not a statement of policy. Its object is to provide a basis for serious thought and discussion. . . . It deals with technical, economic, and social aspects of automation" under six chapter headings: "Automation in Perspective", "The Technical Trends", "The Extent and Rate of Development", "The Impact on Manage-

ment", "The Impact on Labour", and "Conclusions".

The first chapter comments on the merger of developments involving transfer devices and improved mechanical handling, process automatic control, and electronic digital computers, and on their applications to industrial and commercial problems to yield near-automatic factories.

The second chapter deals with trends in automatic machining, process control, and processing of data by digital computers, and the next examines the extent and rate of development of automation, and notes the rapid development of output per capita in Britain and the U. S., the respective roles of large and small firms, the industries most likely to be affected, and the social impact of automation on workers.

Continuing to stress impact, the report examines in the fourth chapter production problems of increased complexity and integration of machines, capital increases, aspects of maintenance, the increased role of the engineer in management, and various industrial training schemes. The fifth chapter considers the impact of automation on labor, chiefly through a detailed examination of the effects on a steel strip mill and the labor aspects of a projected automization of textile mills and chemical processing.

The final chapter draws conclusions from the discussion and points out the uncertainty of current knowledge of the economic and social aspects of automation as compared to knowledge of the technical potentialities. "No one yet knows enough about automation to be dogmatic," the report declares; "much research and exchange of information is [yet] required."

Thomas J. Higgins
Madison, Wis.

Automation, U. S. View

MAN AND AUTOMATION. *Charles R. Walker, president of The Society for Applied Anthropology, and 16 speakers and panelists from industry and education. 117 pp. Published by The Technology Project, Yale University New Haven, Conn., 1956. Single copy, $2.00*

Symposiums on the effects of automation on workers, industry, and the world have become so rife with "old-hat" ideas lately that those who attend them cannot be blamed for dragging their feet into the auditorium under an uncomfortable resolve to stick it out until the last speaker has turned the last page of his cliche-filled manuscript. Attendance is often looked upon as a duty, not a pleasure; an endurance test, not an intellectual excursion; and misgivings are seldom unjustified. So it is easy to understand why such a conference as was sponsored by The Society for Applied Anthropology at Yale last December is reckoned a real discovery. Whether or not a fresh breeze was blowing that day we don't know, but the speakers brought out more new slants on something going stale than can usually be expected from a dozen symposiums together.

Some of the points put forth are controversial, but that is as it should be. Even in run-of-the-mill sessions on automation, there is a certain amount of controversy, although the end result in most cases is a series of academic spats. Here the controversy is tangible. Steered by Society President Charles R. Walker and Yale University's Arthur N. Turner, the speakers deal with problems of transition faced by workers and management, problems inherent in collective bargaining contracts, problems presented by the "short-range" view of automation, problems to be faced by the government as an employer, etc.

One thing that has not been heard very often in this country, although Great Britain had a good share of it during her "automation strike", is pinpointed by Walker, who joined Robert Griffith, a steel mill supervisor, in drawing up "A Case History of a Steel Mill". In the words of a steel worker quoted by Walker, it is this: "I recognize that the company has to put out a lot of production to get back the money on this investment, but the general feeling among the men is that the company is getting a lot more out of the production than the men are sharing."

No work, no effort

Perhaps this is so because the employees see something that Turner, in an excellent and stimulating summary of the conference, seems to have missed. Talking of the steel workers observed by Walker, he says, "For several months they disliked having to be constantly on the alert in case something went wrong. Eventually, however, they expressed considerable satisfaction with their jobs and pride at having learned to control the equipment and operate it successfully." But he adds, "Furthermore, if the mill had been completely automated, the constant watching might not have been necessary or could have been performed by automatic scanning and control devices instead of by men."

Were one of these workers asked to give an opinion on all this, he'd probably say that Turner's thought was unfinished. What would happen to him, he'd ask, if the mill were completely automated and the constant watching were no longer necessary? Sociological studies are fine, the worker would say, just as long as there is something around to study.

Turner uses some material not presented at the conference to introduce the papers that follow his summary. Included in this material are "Leisure and Work: Fusion or Polarity?" by David Reisman and Warner Bloomberg Jr. (University of Chicago), and "Thinking Ahead: Some Effects of Automation" by J. R. Bright (Harvard Business Review). The observations quoted from these articles make sharp contrast. Say Reisman and Bloomberg: "Increasingly the production employees are engaged in communicating with each other concerning what the equipment is doing and maintaining the proper relationships between intricately coordinated machines. Work becomes more abstract, more complex, more intellectual." But, says Bright: Sometimes "there is nothing for the worker to do but 'push a button' or 'monitor' the machinery. In two plants management advised that one of its major mistakes had been to over-estimate the technical requirements of certain jobs."

"Forced" automation

What of management itself? Many of the conference speakers deal with this factor of automation exclusively, and in doing so make some interesting observations. One of them is that some companies have "automated" because they've been forced to—not forced by the competition or by the necessity to produce more goods, but forced by (steel mills take note) manpower shortages. Of course this problem has its roots, not in mills, but in white-collar offices, where the turnover among women employees is high, but that does not detract from its fascination. And whether or not women are responsible for most of the turnover in clerical offices, Kenneth G. Van Auken Jr. of the Bureau of Labor Statistics, one of the speakers, believes they will feel the effects of automation more than any other class of worker.

For the most part management has a healthy and far from insidious eye on the problems. It believes, says Turner, that as the technology becomes more and more complex, it will become more and more necessary that operators of plant and office machinery know what their equipment does whether they need the knowledge on the job or not. And management is not lacking in honest self-appraisal either. It has been known to admit, says Floyd C. Mann of the University of Michigan's Survey Research Center, that it has had antiquated paperwork routines around for a long, long time, and only began thinking about changes when the advent of a computer made changes necessary. In fact, Mann declares, "Many of the economies which accompany the introduction of electronic equipment could be achieved without the equipment, if the same original thinking had been applied to existing operations . . ."

Because unions have protested so loud and so long against automation, little said today about the contribution they make to the complexity of the problem has not been said before. Aware of this, the conference takes particular pains here, with the result that the subject is brought into clear (albeit uncomfortable) focus. Observes Ted F. Silvey of the National AFL-CIO Headquarters Staff in tracing the history of collective bargaining in a Des Moines bacon-packing plant: "The officer of the local union there told me that in the 1955 negotiations they 'bargained out' more job descriptions and job classifications than during the total period of collective bargaining between the union and the company, which was 15 years . . . the people doing the eliminated job continue to receive the same rate of wages they had previously received for the manaul operation—the union contract requires this—and many of these jobs became what is known as red-circle jobs. But the rate for new people . . . is reduced because the requirement is less."

Stronger bargaining power

Does reduction of the labor force compromise unions' ability to bargain because their membership has been reduced? Turner does not think so, and his reason is good and solid. This reduction, he says, will actually strengthen unions' bargaining power, because "the cost to management of a work stoppage will increase with every investment in labor-saving

equipment. As direct labor becomes less important as a cost, its bargaining power may increase."

Two striking thoughts on "productivity" are offered, one by H. F. Kneen of the Safety Car Heating & Lighting Co., and the other by Mark W. Leiserson, a Yale economist. Says Kneen: "I think the government could profitably do more research on reorganizing for less waste in government. When we are faced with need for more productive help (and I'm sure we will be) we might eliminate some from the government and put it to work where it would be creating wealth, rather than spending it." Leiserson believes a company cannot budget itself for the new technology the way it budgeted for other changes, cannot count on the "costs of adjustment" being the same, because automation has forced new considerations, new values, especially personal values. How much would a man salaried by an automated plant or office think he has to "give" in the way of education, experience, etc., to his employer? "Many of the costs of adjustment," Leiserson says, "may not appear directly in the accounts of any particular firm . . . we must be wary of restricting our view-assessing costs and calculating productiveness according to the extent to which individual and corporate claims and liabilities are recognized by the current legal and institutional framework."

A bright, but debatable, note in all this talk about automation is injected by Silvey, who says that when the predictions of some sociologists come true and people have more time for themselves because their work-week has been cut, they "will tend to make living the purpose of life"; that is, "they will be relieved from that acquisitiveness which drives them to obtain personal property beyond all sensible human needs." And yet no one (including Silvey, evidently) has been able to suggest a solution to this nation's marching spectatordom. Until that is licked, until TV values, which definitely include "acquisitiveness beyond all sensible human needs", are somehow changed, the average person will continue to oppose making living the purpose of his life.

Warren Kayes

WHAT'S AHEAD: MEETINGS

NOVEMBER

Third International Automation Exposition and Computer Clinic, Trade Show Building, New York Nov. 26-30

American Society of Mechanical Engineers, Annual Meeting, National Exposition of Power and Mechanical Engineering, Hotels Statler and McAlpin, and the Coliseum, New York Nov. 26-30

DECEMBER

Institute of Radio Engineers, Second Instrumentation Conference, (nuclear instrumentation—industrial applications, missile and wind-tunnel instrumentation), Biltmore Hotel, Atlanta, Ga. Dec. 5-7

Eastern Joint Computer Conference, Institute of Radio Engineers, American Institute of Electrical Engineers, Association for Computing Machinery, Theme: "New Developments in Computers", Hotel New Yorker, New York Dec. 10-12

Radio-Electronics-Television Manufacturers Association, Symposium on Applied Reliability, Bovard Hall, University of Southern California, Los Angeles Dec. 19-20

JANUARY

American Institute of Electrical Engineers and Institute of Radio Engineers, Symposium on Reliability and Quality Control, Hotel Statler, Washington, D. C. Jan. 14-15

American Institute of Electrical Engineers, Winter General Meeting, Hotel Statler, New York Jan. 21-25

FEBRUARY

Instrument Society of America, New York Section, Midwinter Conference (Aircraft Instrumentation), Garden City Hotel, Garden City, Long Island, N. Y. Feb. 7

Western Joint Computer Conference, Hotel Statler, Los Angeles Feb. 26-28

MARCH

American Society of Mechanical Engineers, Nuclear Congress, Convention Hall, Philadelphia March 10-16

Institute of Radio Engineers, 1957 National Convention and Exhibition, N. Y. Coliseum and Hotel Waldorf-Astoria, New York March 18-21

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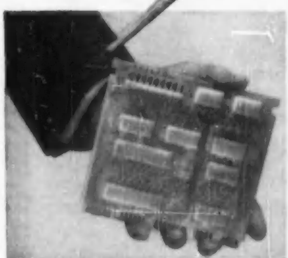

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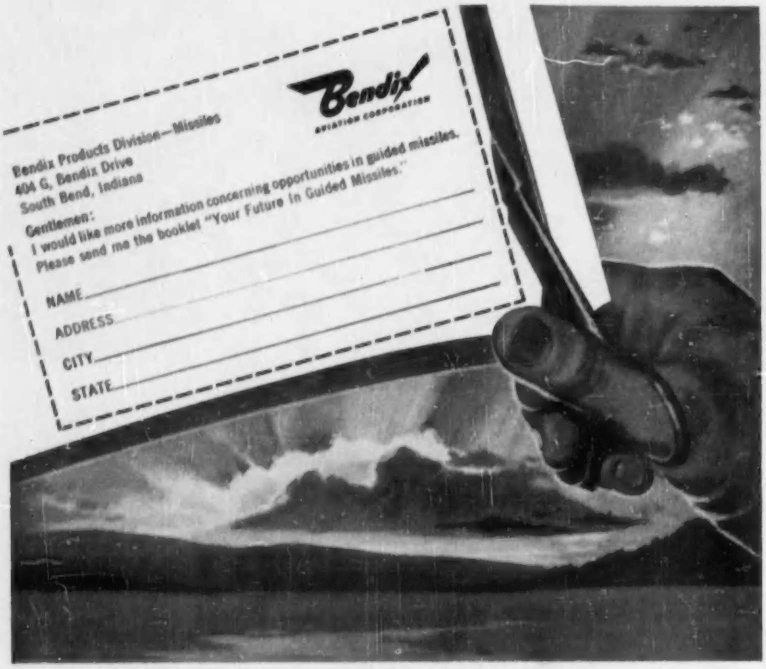

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